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SIMULTANEOUS PALPATION OF THE CRANIOSACRAL RATE AT THE HEAD AND FEET: RATE COMPARISON, INTRARATER AND INTERRATER RELIABILITY, AND ASSESSMENT OF LAG TIME

by
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A thesis submitted to the faculty of The University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Master of Science in the Department of Allied Health Professions, Division of Physical Therapy.

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ABSTRACT

JOSEPH S. ROGERS. Simultaneous Palpation Of The Craniosacral Rate At The Head And Feet: Rate Comparison, Intrarater And Interrater Reliability, And Assessment Of Lag Time (Under the direction of Dr. Philip L. Witt)

Purpose. The purposes of this study were to test the assumption that craniosacral motion is constant throughout the human body, determine the interrater and intrarater reliability of palpating the craniosacral rate at the head and feet, and determine if a lag time was present between the start of craniosacral events at the head and feet. **Subjects.** Twenty-eight adult subjects and two craniosacral examiners. **Method.** With-in subjects repeated measures design. Examiners were blinded to each other. **Results.** Craniosacral rates simultaneously palpated at the head and feet were significantly different. Interrater ICC's were .08 and .19 at the head and feet respectively. Intrarater ICC's ranged from .18 to .30. Lag time trends indicated random phase relationships and faster head rates. **Conclusion.** Results did not support craniosacral motion theory.

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AUTHOR'S NOTICE

The opinions or assertations contained herein are the private views of the author and are not to be construed as official or as reflecting the views of the Department of the Air Force, the Department of the Army, the Department of the Navy, or the Department of the Defense.

Estimations are that one in three of Americans seek medical intervention from alternative health-care practitioners (1). One such intervention that appears to be on the rise is craniosacral therapy. Craniosacral therapy was founded by Dr. John Upledger D.O. in the 1970's. Upledger suggested that the dura mater enclosing the human nervous system exhibited a periodic movement he called craniosacral motion. He surmised that this motion was a normal biological rhythm, inherent to the body and essential for maintaining life, and that abnormalities of this rhythmic motion could lead to pathological conditions (2,3).

Upledger and his associates developed what they called the "pressurestat model" to explain the origins of the craniosacral motion (3,4,5). They theorized that cerebrospinal fluid production goes through cyclic on-off periods, lasting about three seconds each, giving rise to rhythmic changes in intradural pressure. On-off cycles, they claimed, are controlled by a neural reflex feedback loop mechanism involving stretch and compression receptors located within the sagittal suture of the skull. When pressure rises within the dura mater because of cerebrospinal fluid production exceeding reabsorption, tension is created within the sagittal suture. Stretch receptors are activated and signal the inhibition of cerebrospinal fluid production. As the cerebrospinal fluid is reabsorped, intradural pressure decreases, the sagittal suture closes, and pressure receptors are activated. These receptors signal the choroid

plexus to resume cerebrospinal fluid production and another craniosacral cycle begins. No research to date has substantiated Upledger's pressurestat model (6).

Dr. Upledger developed a systematic method of assessment and intervention targeted specifically to normalizing craniosacral motion. He claimed that abnormalities of craniosacral motion could produce or contribute to various pathological conditions including chronic pain and disability, headaches, back pain, arthritis pain, temperomandibular joint dysfunction, learning disabilities, autism, cerebral palsy, scoliosis, digestive disorders, depression, and hyperactivity in children (2). Assessment of craniosacral motion involves palpation of subtle movements of the head, chest, sacrum, or extremities. Dr. Upledger stated that craniosacral motion could be palpated in all living humans anywhere on the body. He claimed that under normal conditions, craniosacral motion is a stable phenomena and is a reliable criteria for clinical evaluation. Intervention for restoring normal craniosacral motion involves the selective application of hand pressure to the patient's body (3).

Upledger and Vredevoogd (3) stated that the craniosacral motion rate is normally between 6-12 cycles per minute. Each cycle of the craniosacral rate has two phases, flexion and extension. They proposed that the craniosacral system is linked to the fascia of the body and, via the fascia, produces motion throughout the body. During the flexion phase, which corresponds to rising intradural pressure, the head expands along the coronal plane and the entire body externally rotates and broadens. After the intradural pressure peaks and declines past a neutral point, the extension phase begins.

During the extension phase the head narrows along the coronal plane and the entire body narrows and internally rotates. The intradural pressure then reaches a nadir and begins to rise. After the pressure rises past a neutral point, another flexion phase begins and one craniosacral cycle is complete. Upledger and Vredevoogd propose that dural motion and extradural fascia motion are interdependent. Karni, Upledger, Mizrahi et al (7) stated that "the craniosacral rate is measurable all over the body and retains a constant value throughout." The only exceptions to this rule, they found, were in patients with paraplegia, severe epilepsy leading to coma, or Guillain-Barre polyneuropathy. In these cases the lower extremity rate could exceed normal rates. Therefore, excepting the above conditions, the craniosacral motion phenomena palpated simultaneously at different locations throughout the body should be related. No research to date has examined this relationship.

Dr. Upledger (5) claimed that over 20,000 persons have been trained by his organization, The Upledger Institute, since 1986. Physicians, dentists, registered nurses, physical and occupational therapists, chiropractors, massage therapists, and acupuncturists are among those trained in and practicing craniosacral therapy. One of the first concepts taught in entry-level craniosacral therapy courses is palpation of craniosacral motion. Since it is presumed that craniosacral motion is most readily palpated at the head (3), beginners are taught to feel the motion at this location first. A standard teaching procedure is to have the beginner stand at the head of a subject and the clinical instructor at the feet. The beginner will then palpate the head and try to assess the

craniosacral motion, particularly identifying flexion and extension phases, while the instructor at the feet provides feedback as to the 'correctness' of the beginner's findings. The implicit understanding between beginner and instructor is that the instructor and beginner are palpating the same thing. No research to date has tested this assumption and the efficacy of this teaching technique.

The importance of using reliable clinical measures to aid in clinical decision making is obvious. Furthermore, the reliability of clinical measures determines the limits of their validity (8,9). One of the primary measures craniosacral therapists use to make clinical decisions is their palpatory assessment of the craniosacral rate (3). Previous researchers have found very poor interrater reliability for the assessment of craniosacral rate (6,10) while intrarater reliability was reported to be high (10). Though the craniosacral rate was distinct from the cardiac or respiratory rates of either the subjects or the examiners (6,10,11), reliability research does not support the assumption that the craniosacral rate is a unique, stable phenomena that can be reliably measured by different examiners. Only one published study has examined intrarater reliability of assessing craniosacral rate (10). No published studies have examined the reliability of palpating the craniosacral rate at locations other than the head, though this practice is common both in clinical and training situations.

The theoretical construct of craniosacral motion assumes that the motion starts as a pressure pulse wave originating within the enclosed cerebrospinal system. Supposedly this pressure wave causes motion that is propagated from the dura to the extremities

via the various interconnections of body tissues. Whether a delay occurs between craniosacral motion occurring at the head and spine and that occurring in the extremities is not known. A lag might exist between temporal events in the craniosacral rate palpated at the head versus those palpated at the hands or feet. To date, no attempt has been made to demonstrate or quantify a lag time between the craniosacral rate palpated at the head and the hands or feet.

Three purposes, therefore, were involved in this study. The first was to test the assumption that if two examiners simultaneously palpate the craniosacral rate at two different locations on the body they should get the same rate. In this study we chose to use the head and feet as the two different locations. The second was to determine the intrarater and interrater reliability for measuring the craniosacral rate at two different locations on the body and determine if reliability varies according to location. The third was to determine if a lag time exists between the start of flexion cycle at the head and the start of flexion cycle palpated at the feet.

Method

Subjects

Twenty-eight subjects participated in this study. Most were recruited by the principal investigator or the examiners, others responded to notices placed in the local area. Of the 28 subjects, 10 were males (mean age=32.40 years, SD=9.38, range=18-49) and 18 were females (mean age=32.44 years, SD=6.83, range=22-48).

Because all humans are believed to have a craniosacral rhythm (3) almost anyone could participate in this study. To be eligible for this study, participants had to be at least eighteen years of age, able to understand instructions, and lie supine for 45 minutes. Since the two locations chosen for study were the head and feet, subjects were also required to have intact lower extremities.

To avoid underestimation of reliability coefficients, reliability studies need to have adequate variance between subjects (8,12). Upledger has stated that various medical conditions can cause alterations in craniosacral rate (2,3). It was therefore assumed that the subjects recruited for this study would have a variety of past or present medical problems that could contribute to a range of observed craniosacral rates. Table 1 summarizes medical history characteristics of our sample population derived from a written questionnaire.

All subjects signed a consent form (Appendix A) prior to participation in this study.

Examiners

Two craniosacral therapists were recruited for this study. Examiner A, a licensed physical therapist, had taken four courses in craniosacral therapy. She had used craniosacral therapy in patient care for a total of 5 years, on 25% of her patients for the first two years and 90% of her patients in the last three years. She had taught 4 workshops on craniosacral therapy for healthcare providers and taught a unit on craniosacral therapy for entry-level physical therapy students.

Examiner B, a registered nurse, had studied craniosacral therapy under Dr. John Upledger for one and a half years. She had taken four courses in craniosacral therapy. She had used craniosacral therapy in patient care for the last 17 years and at the time of this study had a full-time private practice in craniosacral therapy. She had also taught 4 workshops on craniosacral therapy for healthcare practitioners.

Both examiners reported that they routinely assess craniosacral motion when treating their patients.

Instrumentation

Each examiner's palpatory findings were recorded via activation of a foot switch (Figure 1). When the foot switch was depressed no signal was present. When the examiner raised the ball of their foot, a signal occurred. Signals were captured via an analog-to-digital data acquisition system (Biopac-MP100) connected to a Macintosh PC. The analog signal was converted to a pulsewave that was plotted as a function of time (Figure 2).

To achieve adequate blinding of examiners, the foot switches were constructed so that their operation was silent. Silent operation was essential to eliminate auditory cueing between examiners.

Procedure

Both examiners were instructed in proper use of the foot switches. They were instructed to activate the switch each time they felt the beginning of a flexion phase. During pilot work and

prior to each data collection session, the examiners were tested using the foot switches to respond to a known visual stimulus. Testing the examiners served the dual purpose of assessing proficiency in using the switches and making sure the instrumentation was working properly. For each test, both examiners demonstrated 100% accuracy in using the switches.

The examiners were allowed to use palpatory techniques of their choice and were not given any instruction regarding how to palpate the head or feet.

In our study, craniosacral rate was the dependent variable. To collect craniosacral rate data, a within-subjects, repeated measures design was used. Independent variables were examiner, location, and measurement trial. Each independent variable had two levels, therefore eight data points were collected for each subject. For example, rate data for each subject included the following rates: Examiner A at the head, trial 1; Examiner B at the feet, trial 1; Examiner A at the head, trial 2; Examiner B at the feet, trial 2; Examiner A at the feet, trial 1; Examiner B at the head, trial 1; Examiner A at the feet, trial 2; and Examiner B at the head, trial 2.

Each subject was positioned supine on a standard treatment plinth. One examiner was placed at the head (Figure 3) and the other at the feet (Figure 4). Visual blinding of the examiners was accomplished by hanging a standard cubicle privacy curtain over the subject's waist to block the examiners from seeing each other. To further aid in blocking auditory cues from either the switches or the examiners, a running fan was used to provide background white noise. The subject would then rest for a period of two minutes on

the plinth. During this period, the examiners were not allowed to touch the subject. The principal investigator would then state, "begin palpating the rhythm now", whereby both examiners would begin palpating at their respective locations. When both examiners began using their foot switches, an LED would turn on, cueing the principal investigator to begin data collection. The LED was located so that only the principal investigator could see it. Two continuous minutes of data were then collected after which the principal investigator would instruct the examiners to stop palpating. The examiners would then remove their hands from the subject. Since it has been suggested that craniosacral motion may change for a few seconds up to 1 minute following palpation (6), we allowed two minutes to transpire between measurements to allow craniosacral motion to return to baseline. So the subject would then lie still for another two minutes, after which the above measurement procedure was repeated. After the second measurement was taken, the examiners switched locations and two more measurements were taken. A total of four measurement trials were taken for each subject. To avoid systematic bias of rate data, examiner starting locations were alternated across data collection sessions so that examiner A started at the head for 13 subjects and examiner B started at the head for 15 subjects.

Data Analysis

All pulsewave data were analyzed using AcKnowledge® software, version 2.1. The craniosacral rate in cycles per minute was calculated by taking 60 seconds and dividing it by the average

rise-to-rise (beginning of flexion phase-to-beginning of flexion phase) time interval over the two minute trial. Figure 5 provides an example calculation of craniosacral rate.

To better understand phase relationships between the craniosacral rate measured simultaneously at the head and feet, we wanted to determine if a lag time was present between start of flexion phase at the head and start of flexion phase at the feet. Lag time was defined as the difference in time between the first head pulse and the first foot pulse occurring after the first head pulse, the delay between the second head pulse and the next foot pulse, and so on. Expressed this way, a positive lag time means that the head pulse occurred first and the corresponding foot pulse sometime after. A negative lag time means that the foot pulse occurred first and the corresponding head pulse sometime after. Negative lag times could occur if the craniosacral rate at the feet was faster than that of the head. Figure 6 gives examples of lag time determination. Lag times were gathered from all measurement trials for each subject so that each subject had a unique population of lag times.

Data was analyzed using SPSS® for Windows, version 6.1. Applicable descriptive statistics for craniosacral rate were performed. Differences between craniosacral rates taken simultaneously at the head and feet were analyzed using repeated measures ANOVA. Reliability coefficients were calculated using ICC (2,1) as described by Shrout and Fleiss (13). To better interpret ICC's, contributions of variance due to between-subjects and examiner-subject interactions were analyzed using a custom-

modeled factorial ANOVA. Lag times were described using box plots. For both ANOVA's, significance was assumed at $p < .05$ level.

Results

Table 2 shows craniosacral rate mean, standard deviation, and range pooled for each examiner and for each examiner by location.

Data assumptions for repeated measures ANOVA were met except for normality. Repeated measures ANOVA is robust to violations of this assumption (14). Table 3 shows results of repeated measures ANOVA. Since the interaction between examiner and location was significant, simple effects for examiner and location were calculated. Main effects for trials and all interactions involving trials were not significant and are not included in Table 3. In addition to ANOVA, Pearson's product-moment correlation coeffcient between rates taken simultaneously at the head and feet was calculated, Pearson's r= -.068. Mean absolute difference between simultaneous head and feet rates was also determined, mean absolute difference=1.822, 95% CI for the mean=1.579 to 2.065. Figures 7a, 7b, 7c, and 7d show raw data difference plots for simultaneous palpation of head and foot rates.

Table 4 shows intrarater and interrater ICC's and Pearson's r coefficient by location. Because observed ICC's were low, the reliability analysis was extended to identify possible sources of poor reliability. Lahey, Downey, and Saal (12) observed three sources of poor reliability which can affect ICC's: the presence of rater-subject interaction, lack of variance between subjects, and no correlation present between the judges. Each of these possible

sources was examined. Since it is not possible to examine the significance of rater-subject interaction (12) separate from the error term or obtain an unbiased test of between subjects variance (15) using repeated measures ANOVA, a custom-modeled, factorial ANOVA was performed. In the model, main effects of rater, location, trial, and subjects, two-way interactions involving subjects (which are the error terms used to determine main effects in repeated measures ANOVA), and all possible three-way interactions were examined. The residual, now a fair estimate of random error, consisted of the two-way interaction between trial and location plus the fourth order interaction. Table 5 shows the results of the custom-modeled, factorial ANOVA.

Figure 8 shows box plots of lag time for each subject.

Interpretation

Since the results of this study need to be interpreted in light of the reliability findings, these will be addressed first. The ICC's for both intrarater and interrater reliability in this study were low to non-existent (16). Mitchell (8) illustrated how a lack of between-subject variance can affect reliability coefficients. She pointed out that the reliability coefficient equals the true score variance divided by true score variance plus error variance, so that if both the true score variance (between-subjects variance) and error variance are equal to 10, the reliability coefficient would equal .50. However, if true score variance equals 40 and the error variance equals 10, the reliability coefficient would equal .80. Reliability studies should therefore seek to test heterogeneous

groups. The significance of differences between subjects (F=3.39, p=.001) (See Table 5) demonstrated that the sampled craniosacral rates came from a heterogenous population (16) and that a lack of between subjects variance did not contribute to low reliability in this study.

The rater-subject interaction was significant (F=2.04, p=.030) (See Table 5). This finding can be interpreted to mean that this interaction made up a significant portion of the error term used to calculate the interrater ICC's. Since only two raters participated in this study, it can therefore be assumed that a lack of agreement between the raters caused the low interrater ICC's.

Review of intrarater between trials correlations (See Table 4) showed a range of Pearson's r to be .17 to .30 (p=.384 to p=.120). Between rater correlations (Also Table 4) showed Pearson's r to be .12 (p=.390) and .23 (p=.082). No significant correlations between scores indicates either a lack of agreement between raters or that the raters are incapable of accurately judging 'true' scores (12). The former is believed to be the case here. Therefore, the low intrarater and interrater ICC's found in this study represent a lack of agreement between craniosacral rate measurements taken by the two examiners. Given the all-around low reliability of measuring the craniosacral rate in this study, the question of reliability differences between locations becomes unnecessary.

Because of the low reliability of measures in this study, the results of repeated measures ANOVA for differences in head and foot rates and the quantification of lag times need to be interpreted cautiously. Unreliable data sufficiently degrades any statistical

analysis and solutions may reflect only measurement error (17). Therefore caution should to be taken when generalizing the results of head and foot differences and lag times.

The results of repeated measures ANOVA showed significant differences between the examiners at both locations (Head, $F=35.79$, $p<.05$; Feet, $F=8.69$, $p<.05$) for craniosacral rate measurements taken simultaneously at the head and feet. Examiner A had significantly different craniosacral rates for head and feet ($F=20.89$, $p<.05$), while Examiner B did not ($F=.44$, $p>.05$). These findings can be interpreted to mean that the examiners did not agree on the craniosacral rate for a given subject on a given trial. Therefore, the assumption of no differences between simultaneous head and foot rates cannot be supported by the results of this study.

Another significant finding from the simultaneous palpation data (See Figures 7a, 7b, 7c, and 7d) is where obvious and large discrepancies of rater findings occur, such as when one rater is palpating zero craniosacral rate while the other is palpating a non-zero rate. Upledger and Vredevoogd (3) stated that a total craniosacral system 'shut down' is possible and is characterized by a cessation of all craniosacral motion. This cessation of motion is what they call a 'still point'. They stated that still points can be induced by the craniosacral therapist gently applying resistance to craniosacral motion until the motion completely stops. A still point can last from a few seconds to a few minutes. They stated that still points are most commonly induced from the head or sacrum but can also be induced from the feet as well. For this study, it was assumed that examiner findings of zero craniosacral rate over the

two minute data collection period meant that a still point had occured. Upledger and Vredevoogd's account of the still point was interpreted to mean that if a 'total craniosacral system motion shut down' occured and craniosacral motion became 'perfectly still' , then no craniosacral rate should have been discernible throughout the body. The results of this study contradict Upledger and Vredevoogd's statements regarding still point activity. Those cases where one therapist was palpating a craniosacral rate of zero and the other was not suggest that the two examiners were palpating two different phenomena rather than the single stable occurence craniosacral motion is theorized to be.

Rates could have been the same, but totally out of phase. Plotting the distribution of lag times provided an indication of relative phase relationships between the craniosacral rate palpated at the head versus the feet (See Figure 8). Box plots describe distribution and are well discussed elsewhere in statistics texts (14). A brief description is given here. The box plot describes minimal score, maximal score and is divided into quartiles. The 'arms' of the box are the first quartile (25th percentile) and third quartiles (75th percentile). The 'box' portion consists of the middle two quartiles. The dark line in the box is the median and divides the middle two quartiles. As was noted earlier, no one has determined if a lag time exists between the craniosacral rate at the head and feet. Theoretically, if the craniosacral rates at the head and feet were in phase, we would have expected a lag time distribution with a fairly narrow range of low positive numbers (signifying that head rates came prior to foot rates). It was predicted beforehand that

the lag time would be between 0 and 5 seconds (the dark reference line in Figure 8). From observing Figure 8, it was apparent that the data did not support this prediction. The large variance of lag times, with the inclusion of negative numbers, meant that the phase relationship appeared to be random in many cases. This finding could be reflective of random error in measuring the craniosacral rate. Another finding is that most of the boxes are in the large positive range. This meant that in most cases, the head rate was faster than the foot rate. In those rare instances where the head rate and foot rate appeared to be in phase, the lag time was about 1 to 5 seconds as predicted. Figure 9 shows the actual waveform data collected from one such a case. More often, however, phase relationships appeared random such as those shown in Figures 10a and 10b.

Discussion

The findings of our study raise important issues regarding the reliability of measuring the craniosacral rate and the validity of Upledger and Vredevoogd's craniosacral motion theory. The research design used in this study permitted investigation of whether the examiners were actually measuring the same thing, at the same time, within the same subject. The results suggest that at most times the examiners were not measuring the same thing and that major assumptions regarding craniosacral motion require further investigation before those assumptions can be considered valid.

As noted earlier, Upledger and Vredevoogd (3), considered the normal range of the craniosacral rate to be between 6 and 12 cycles

per minute. Wirth-Patullo and Hayes (6) examined the interrater reliability of three examiners on 12 subjects. The average craniosacral rates measured by the three examiners were reported to be 4.50, 5.92, and 7.00 cycles per minute. The range of rates was reported to be between 3.0 and 9.0 cycles per minute. Norton, Sibley, and Broder-Oldbach (18) had a single experienced examiner measure the craniosacral rate in 20 subjects. They reported an average cycle length of 16.41 +/- 3.34 seconds, giving them an average rate of 3.66 cycles per minute for the 20 subjects. Sibley, Broder-Oldbach, and Norton (19) examined interexaminer reliability of measuring the craniosacral rate by having ten examiners palpate the rate in one subject. They reported an average cycle length of 18.90 +/- 7.78 seconds, giving them an average rate of 3.18 cycles per minute. We reported the average craniosacral rate measured by Examiner A to be 4.37 cycles per minute and Examiner B to be 3.21 cycles per minute. We found the rates for both examiners to range from 0 to 8.42 cycles per minute. The average rates in our study agreed particularly well with those by researchers Norton, Sibley, and Broder-Oldbach, who used similar instrumentation techniques. Our results agree with the above previous studies in finding average craniosacral rates below the normal range reported by Upledger and Vredevoogd (3).

The interrater reliability ICC's in our study agree with those reported by other authors. Wirth-Patullo and Hayes (6) reported an interrater ICC of -.02 between the three examiners in their study. The ICC's between pairs of raters was reported to be -.33, -.60, and .49. Hanten, Dawson, Iwata, et al (10) had two examiners palpate

the craniosacral rate twice each on 40 subjects. They reported an interrater ICC of .22. This study found interrater ICC's of .08 at the head and .19 at the feet. What we found surprising was the low intrarater ICC's . Hanten, Dawson, Iwata, et al reported intrarater ICC's of .78 and .83 for their two examiners. We found intrarater ICC's of .18 and .26 at the head and .30 and .29 at the feet. Because we wanted to examine the relationship between simultaneous findings at the head and feet we allowed still points, while Hanten, Dawson, Iwata et al did not include still points in their study (WL Hanten, personal communication, 4 March, 1997). Since it is possible that an examiner could induce a still point on one trial and not on the other, and therefore reduce intrarater reliability, we filtered our data and calculated ICC's excluding those cases that had still points. Using filtered data, we found intrarater ICC's of .48 and .29 at the head and .32 and .60 at the feet. Filtered intrarater ICC's did increase but were still in the low to moderate range and still much lower than those reported by Hanten, Dawson, Iwata et al. The interrater ICC's using the filtered data were worse than unfiltered interrater ICC's. Consistently low interrater ICC's reported by previous researchers and in this study, challenge Upledger's and Vredevoogd's (3) assumption that craniosacral motion is a stable phenomena that can be measured reliably by palpation.

Our findings that during simultaneous palpation of the craniosacral rate at the head and feet, one examiner can record a still point while the other is measuring a consistent rate challenge Upledger and Vredevoogd's (3) statements that craniosacral motion is a unique physiologic phenomena distinct from other bodily

rhythms and interactions between the subject and examiner. Previous studies have supported the notion that craniosacral rate is different from the heart and respiration rates of either the examiner or the subject (6,10,11,20). Other factors, however, may better explain or predict measured craniosacral rates. For example, Burch, Cohn, and Neumann (21) and Christ et al (22) described spontaneous rhythmic volume changes in the digits and limbs of subjects that occured at rates similar to those described by Upledger for the craniosacral rhythm. These rhythmic volume fluctuations were independent of respiratory and cardiac rates and were thought to be related to autonomic vasomotor function. Burch, Cohn, and Neumann (21) measured the rates of simultaneous volume changes in the fingers, toes, and ears and found these rates to be different. It is possible that the examiners in our study were measuring this type of volumetric change within our subjects or some combination of volume changes of their fingers with those of the subject's head and feet. Another possible factor is that the examiners were at times measuring their own craniosacral rhythm or a combination of their own rhythm and that of the subject's. The results from the repeated-measures ANOVA showed that for a given subject, examiners did not agree on rates taken simultaneously and that Examiner A measured different rates at the head and feet while Examiner B did not, implying that Examiner B was the only one measuring a consistent rate within each subject. These ANOVA results suggest that each examiner was probably measuring something different and each may have unique factors that account for their rate findings.

The results of our study challenge the assumption that the craniosacral rate measured simultaneously at the head and feet would be the same. The instruction of beginners in craniosacral palpatory skills often rely on this assumption. The observed mean absolute difference of 1.822 cycles per minute may not have clinical significance, but would certainly impact the teaching methods used in craniosacral therapy education. Visual and auditory cues between expert and beginner may allow both to obtain the same results. Blinding the examiners to each others findings, as was the case in our study, did not permit such cues and the examiners obtained different results.

Future Research

As Echternach (23) succinctly put it, "If I were a proponent of the proposition that the cranial motion existed, I would certainly be working extremely hard to show that this physiologic event can be recorded and displayed to others in a satisfactory manner....because I would be basing so much of my therapy and theory for therapy on this phenomena." Unfortunately, little research has been done to support the existence of craniosacral motion as proposed by Upledger and Vredevoogd.

One possible cause of poor interrater agreement in our study was the disparity between examiner experience. Examiner A had used craniosacral therapy in patient care for 5 years while Examiner B had used it for 17 years. Though both our examiners were generally considered to be experts and should have been equally qualified to measure craniosacral rate, Sibley, Broder-Oldbach, and

Norton (19) have suggested that reliability may be a function of years of experience. Matching examiners by experience may increase reliability.

Only craniosacral rate was measured in our study. Upledger and Vredevoogd (3) stated that craniosacral clinicians could gain important diagnostic and prognostic information about their patients by palpating the craniosacral motion for rate, amplitude, symmetry, and quality. Upledger (20) used a19-item test to determine interexaminer agreement on measuring craniosacral motion. Test items qualitatively described different parameters of craniosacral motion. The examiners would rate each item using a predetermined 5-point rating scale. Upledger reported relatively high interexaminer agreement when using this test and allowing a +/- 1 point deviation on the rating scale. This level of agreement may have been overestimated due to the limited range of scale scores and the leeway allowed for agreement. Since we only measured rate, we may have missed capturing other significant parameters of craniosacral motion. Researchers conducting reliability studies in the future may want to incorporate gathering both quantitative and qualitative information into their design. However, if expert examiners cannot agree on the start of flexion phase, as was the case in this study, how can they agree on other, more complex, qualitative events? This question may be worth investigating.

Development of instrumentation that could reliably measure and document craniosacral motion would provide a 'gold standard' in which to compare palpatory findings in reliability studies. Several

investigators have claimed to have measured the craniosacral motion in humans using instrumented techniques (7,24,25). Frymann (24) used differential transformers placed on each side of subjects' heads to measure expansion and contraction of the cranium. She presented over a dozen recordings of what she claimed to be the craniosacral rhythm, but failed to adequately report her subject population and also failed to demonstrate the reliability of her instrumentation. Frymann also suggested that rhythmic volume changes in the extremities correspond with craniosacral motion. Karni, Upledger, Mizrahi et al (7) and Upledger and Karni (25) used strain plethysmography to measure rhythmic volume changes in either the forearms or thumbs of approximately three subjects. These authors claimed that the volumetric changes they measured were reflective of the craniosacral motion in their subjects. Reliability of strain plethysmography for measuring these volume changes was not reported. The physiologic relationship of craniosacral motion to volume changes in the thumb or forearm was not explained by these authors and currently remains unclear. If the volume changes measured by Upledger and associates are the same as those measured by Burch, Cohn, and Neumann (21) and Christ et al (22), then craniosacral theory needs to be expanded to explain the relationship between craniosacral motion and limb volume changes and how the rhythm can be simultaneously different throughout the body as described by Burch, Cohn, and Neumann. Also, none of the above craniosacral studies have been replicated by independent investigators.

Data from cerebrospinal fluid pressure monitoring could promote the reliability of palpating craniosacral motion and support its validity as a physiological phenomena. Lundberg (26) described oscillations in intracranial pressure that occur at a regular frequency of 4 to 8 cycles per minute. He called these oscillations "C-waves". The amplitude of C-waves was reported to be from just discernible to 20 mm Hg. Heifetz and Weiss (27) and Pityk, Piantanida, and Ploeger (28) have demonstrated a correlation between intracranial pressure and skull bitemporal diameter. Increases in living human skull diameter occured with intracranial pressure increases of 15 to 20 mm Hg (27). Though these studies may provide some support for craniosacral theory, the relationship between cerebrospinal fluid pressure changes and palpatory findings has yet to be demonstrated. Future studies could examine this relationship.

Conclusion

This study examined simultaneous palpation of the craniosacral rate at the head and feet by two blinded examiners. Examiners had signifcantly different rate measurements. The mean absolute difference between the two rates was 1.82 cycles per minute. Intrarater reliability coefficients for both locations ranged from .18 to .30. Interrater reliability coefficients were .08 for the head and .19 for the feet. The finding that one rater could palpate a still point while the other could simultaneously palpate a consistent craniosacral rate within the same subject suggests that the examiners were palpating different phenomena. Lag time

distributions showed large variances indicative of random phase relationships between the beginning of craniosacral cycle at the head and beginning of the cycle at the feet. The majority of lag time distributions contained high positive numbers, indicating that in the majority of cases, the craniosacral rate at the head was faster than that of the feet. The results of this study did not support the craniosacral theory of Upledger and Vredevoogd.

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FIGURE LEGENDS

Figure 1. Foot switch used to obtain craniosacral rate data.

Figure 2. Sample craniosacral rate data.

Figure 3. Examiner placed at head.

Figure 4. Examiner placed at feet.

Figure 5. Craniosacral rate calculation.

Figure 6. Lag time determination.

Figure 7a. Simultaneous palpation of craniosacral rate data, Trial 1, Examiner A at the Head, Examiner B at the Feet.

Figure 7b. Simultaneous palpation of craniosacral rate data, Trial 2, Examiner A at the Head, Examiner B at the Feet.

Figure 7c. Simultaneous palpation of craniosacral rate data, Trial 1, Examiner A at the Feet, Examiner B at the Head.

Figure 7d. Simultaneous palpation of craniosacral rate data, Trial 2, Examiner A at the Feet, Examiner B at the Head.

Figure 8. Lag time distribution by subject. N = number of lag times obtained for each subject.

Figure 9. Example of in-phase craniosacral rates rarely obtained in this study.

Figure 10a. Example of out-of-phase craniosacral rates commonly obtained in this study.

Figure 10b. Example of out-of-phase craniosacral rates commonly obtained in this study.

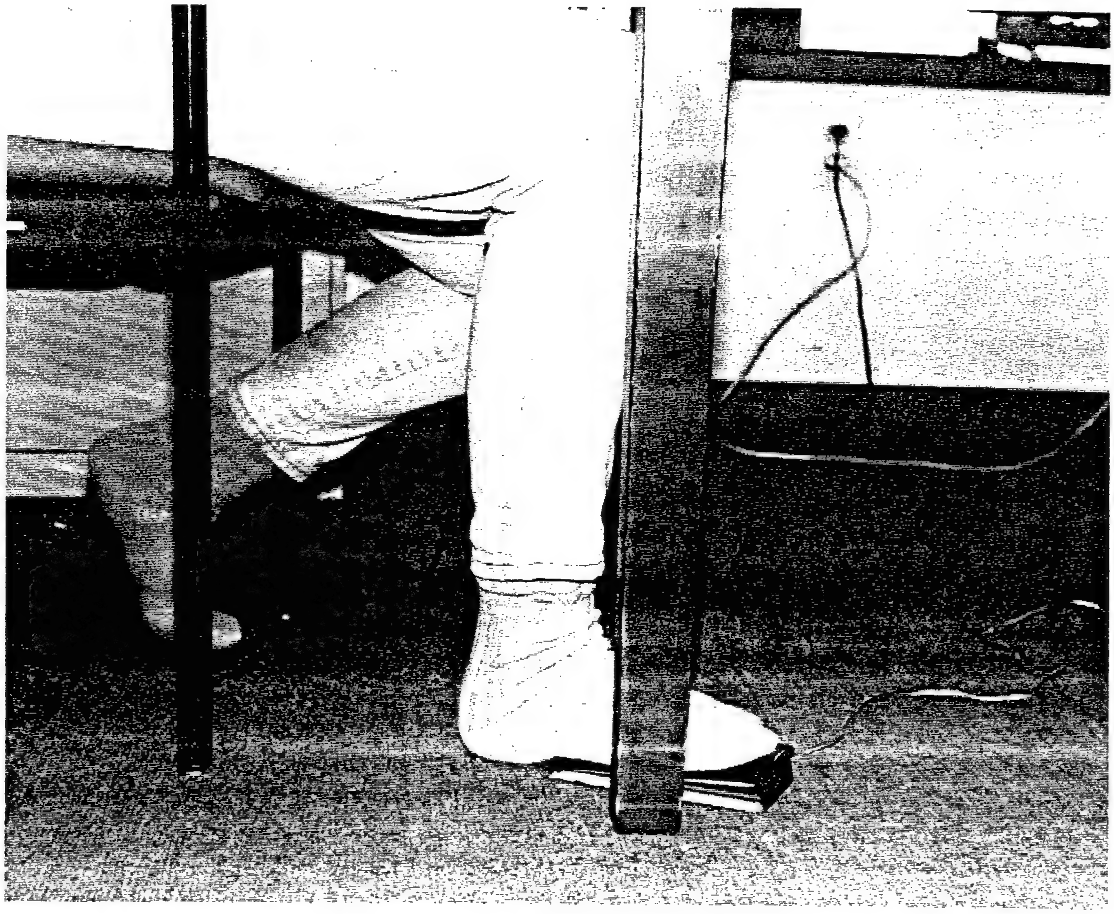


Figure 1.

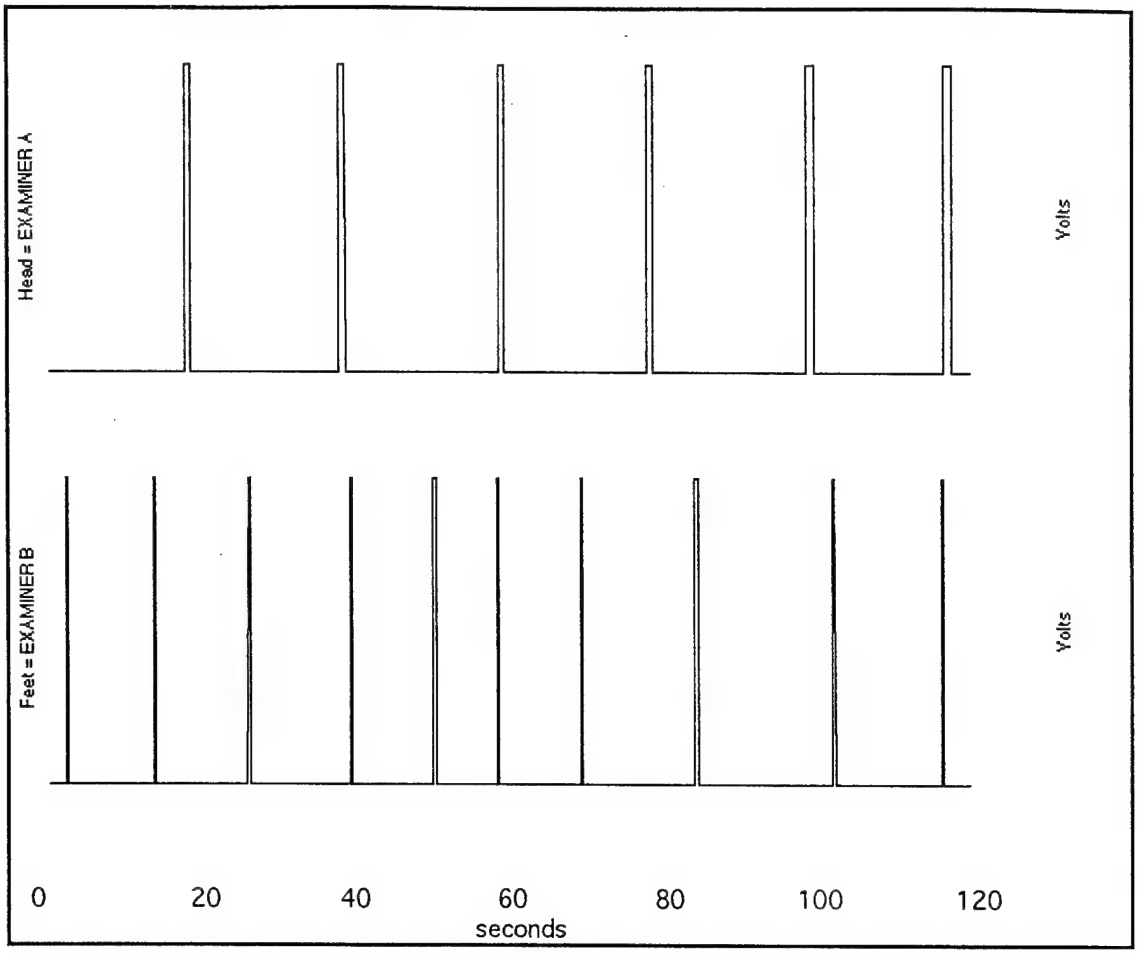

Head = EXAMINER A
Volts
Feet = EXAMINER B
Volts
0
20
40
60
80
100
120
seconds

Figure 2.

Figure 3.

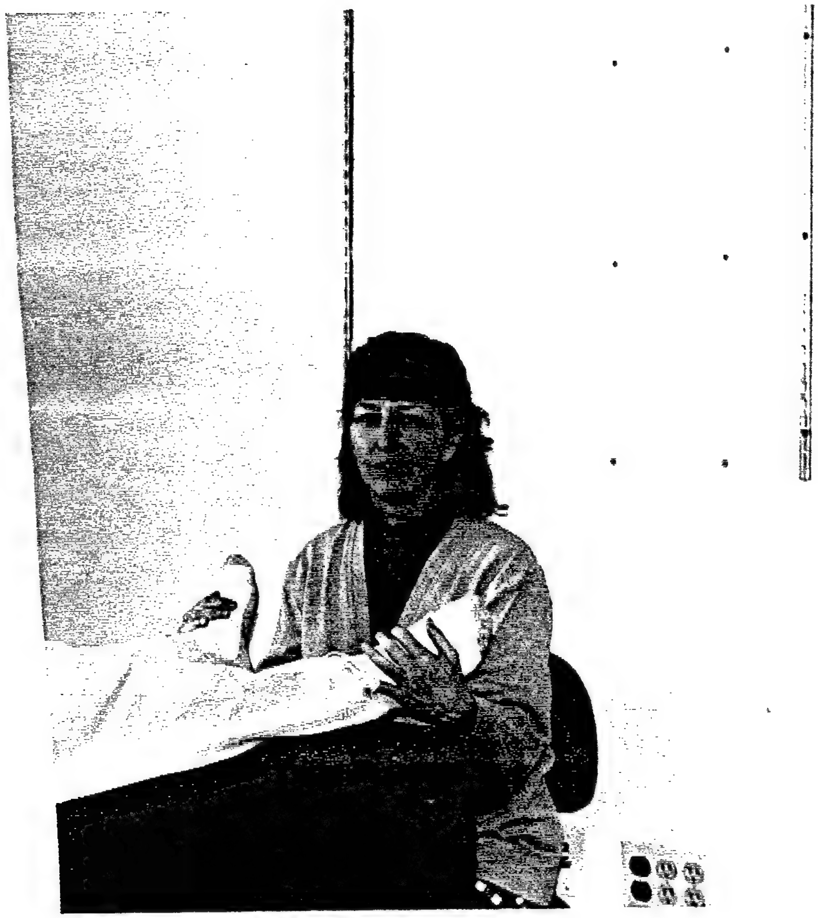


Figure 4.

$$\text{Craniosacral Rate (cycles per minute)} = \frac{60 \text{ sec}}{\text{ave } \Delta T}$$

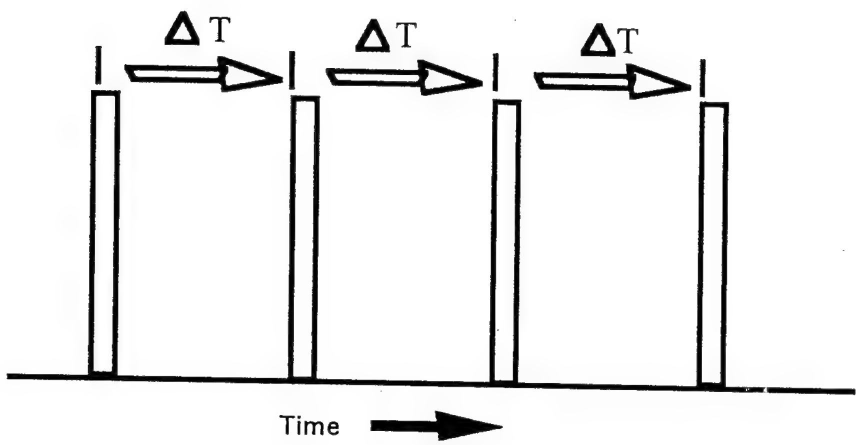
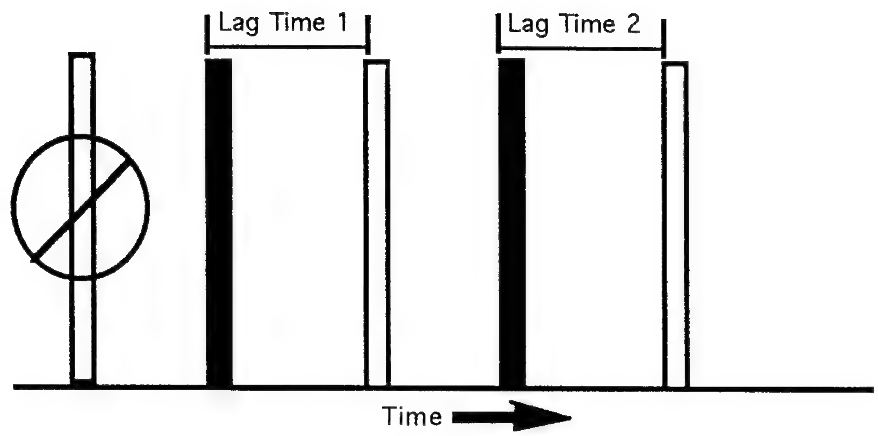


Figure 5.



■ = HEAD

□ = FEET

Figure 6.

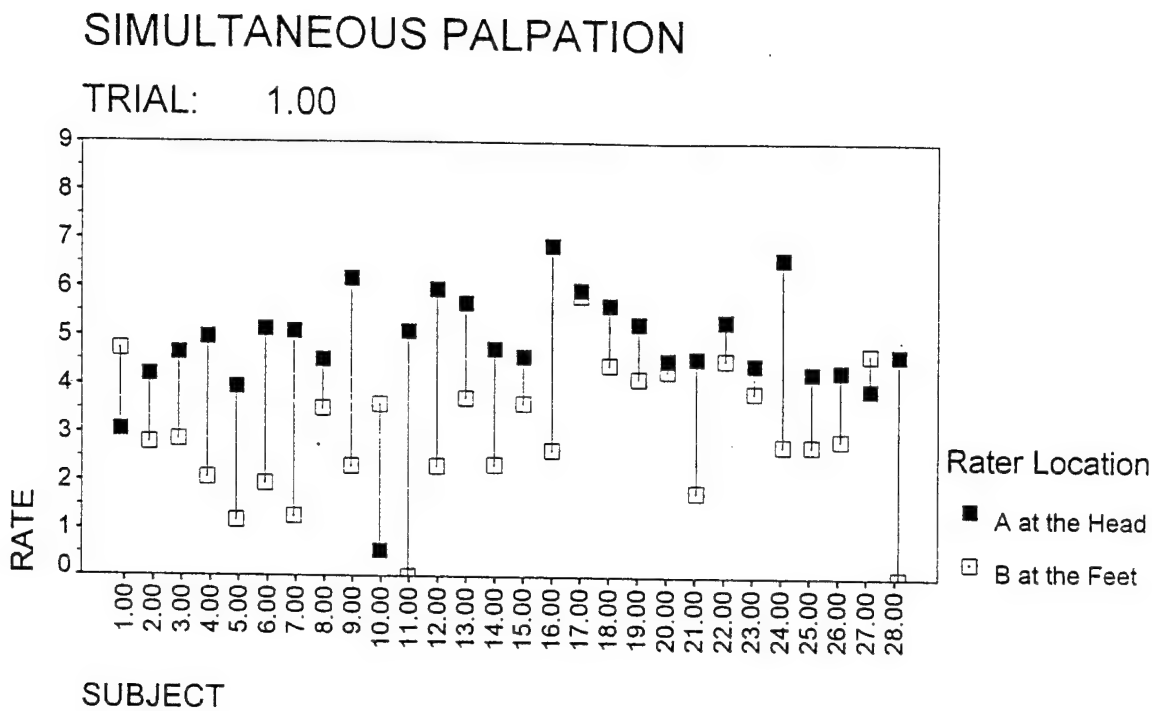
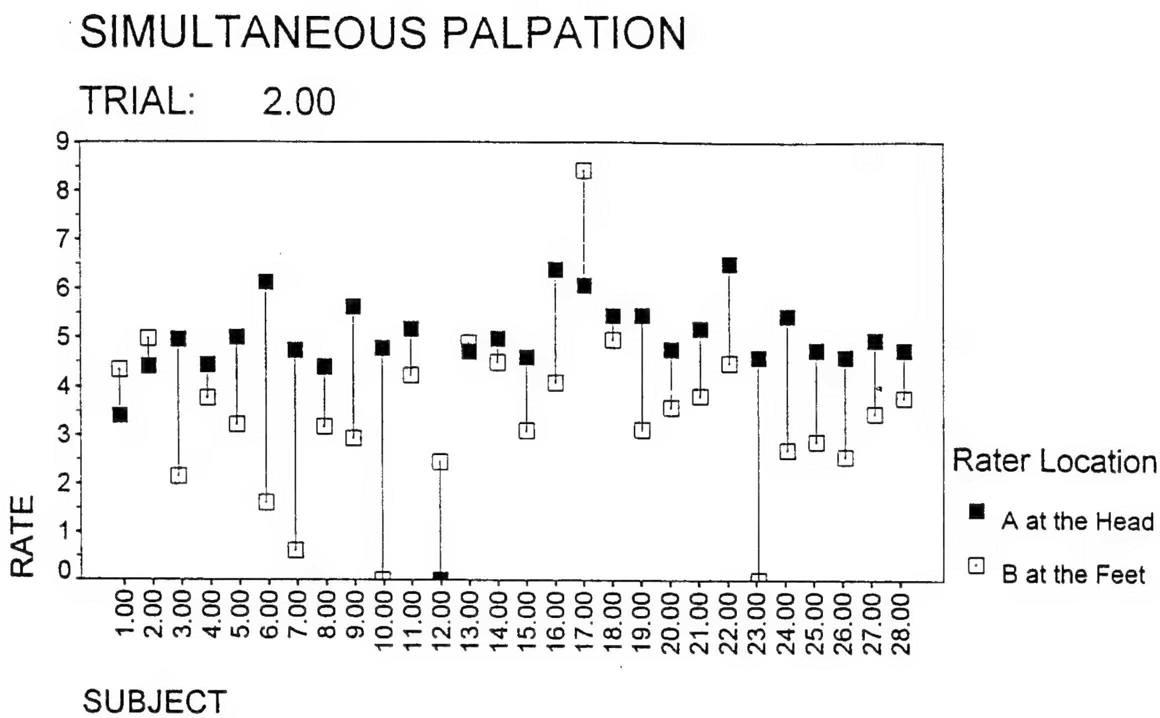
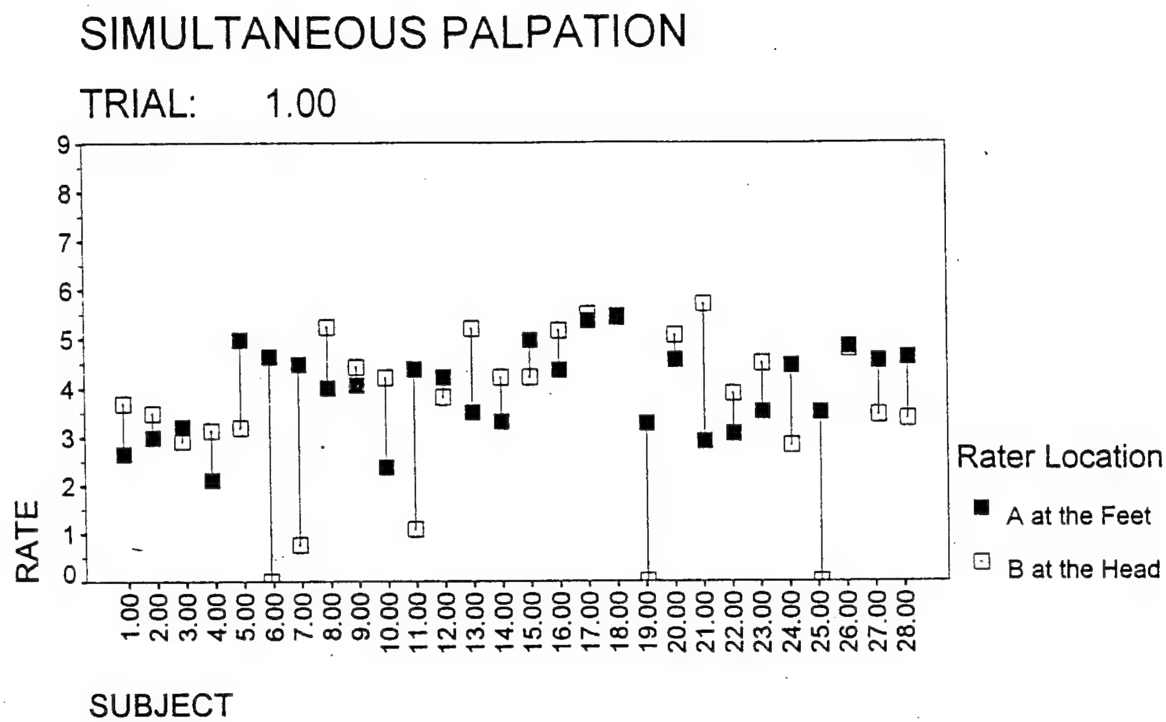

SIMULTANEOUS PALPATION
TRIAL: 1.00
RATE
0
1
2
3
4
5
6
7
8
9
SUBJECT
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00
16.00
17.00
18.00
19.00
20.00
21.00
22.00
23.00
24.00
25.00
26.00
27.00
28.00
Rater Location
A at the Head
B at the Feet

Figure 7a.



SIMULTANEOUS PALPATION
TRIAL: 2.00
RATE
0
1
2
3
4
5
6
7
8
9
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00
16.00
17.00
18.00
19.00
20.00
21.00
22.00
23.00
24.00
25.00
26.00
27.00
28.00
SUBJECT
Rater Location
A at the Head
B at the Feet

Figure 7b.



SIMULTANEOUS PALPATION
TRIAL: 1.00
RATE
0
1
2
3
4
5
6
7
8
9
SUBJECT
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00
16.00
17.00
18.00
19.00
20.00
21.00
22.00
23.00
24.00
25.00
26.00
27.00
28.00
Rater Location
A at the Feet
B at the Head

Figure 7c.

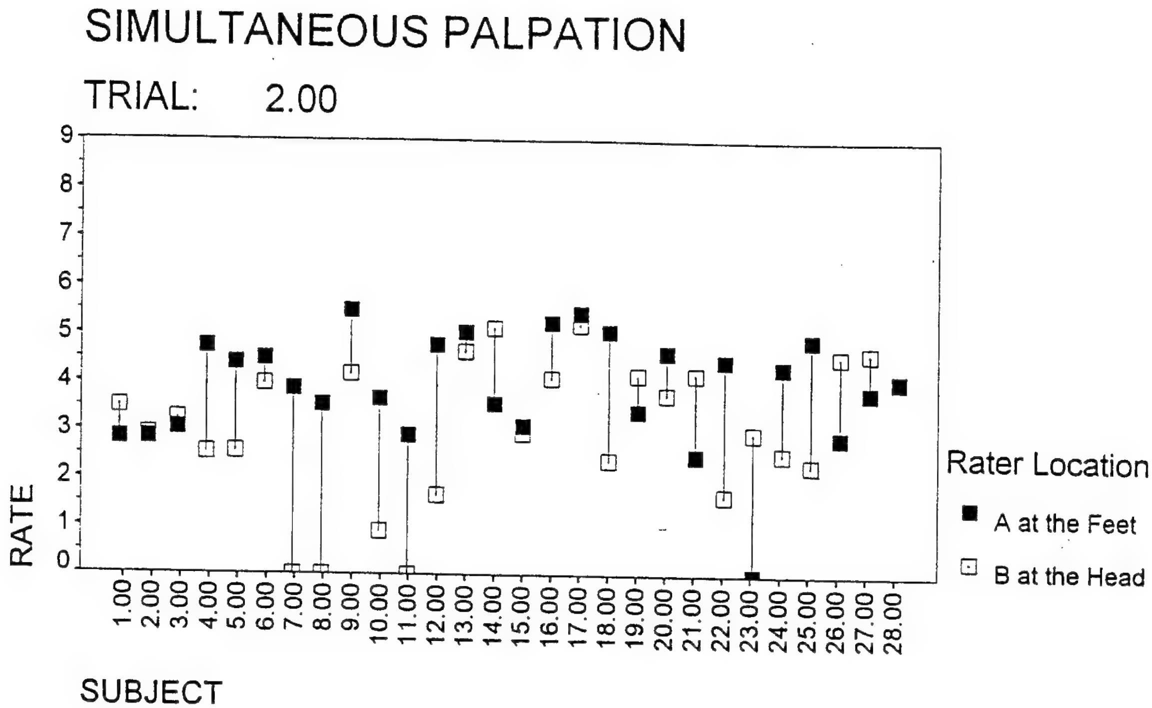
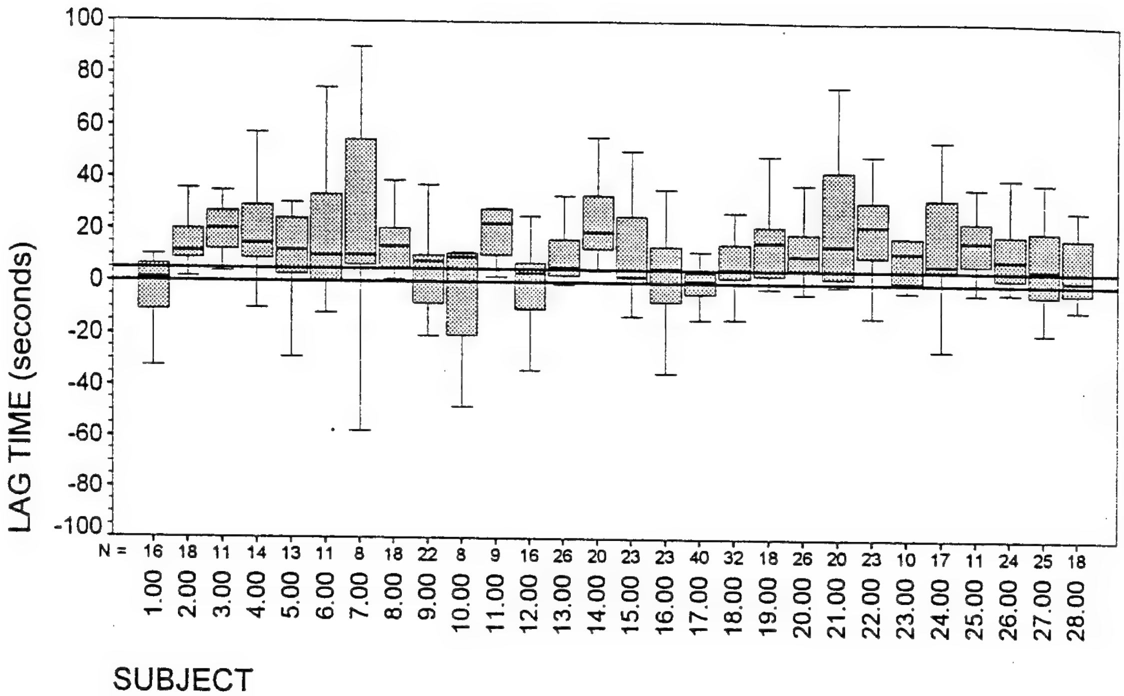

SIMULTANEOUS PALPATION
TRIAL: 2.00
RATE
9
8
7
6
5
4
3
2
1
0
SUBJECT
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00
16.00
17.00
18.00
19.00
20.00
21.00
22.00
23.00
24.00
25.00
26.00
27.00
28.00
Rater Location
A at the Feet
B at the Head

Figure 7d.



LAG TIME (seconds)
100
80
60
40
20
0
-20
-40
-60
-80
-100
N = 16 18 11 14 13 11 8 18 22 8 9 16 26 20 23 23 40 32 18 26 20 23 10 17 11 24 25 18
1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00 11.00 12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00 21.00 22.00 23.00 24.00 25.00 26.00 27.00 28.00
SUBJECT

Figure 8.

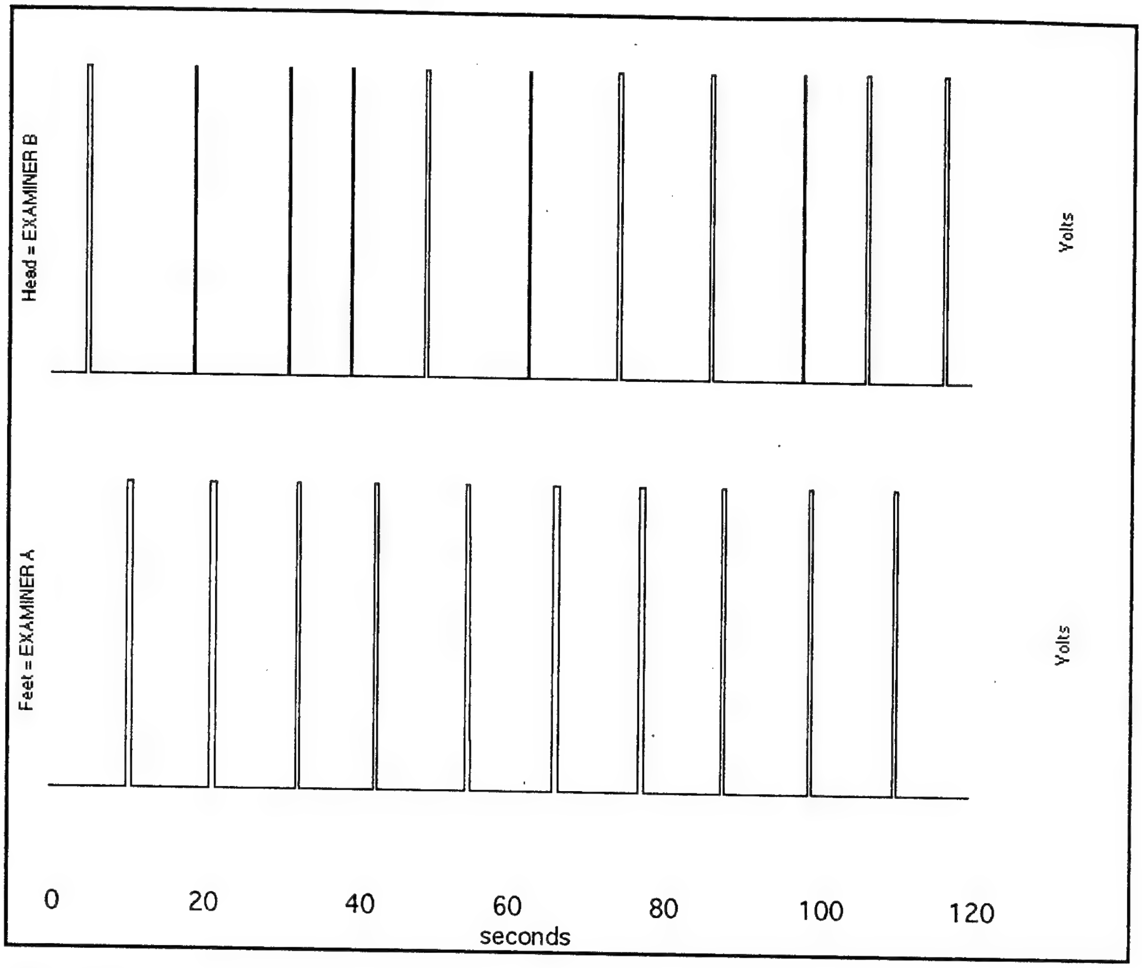

Head = EXAMINER B
Volts
Feet = EXAMINER A
Volts
0
20
40
60
80
100
120
seconds

Figure 9.

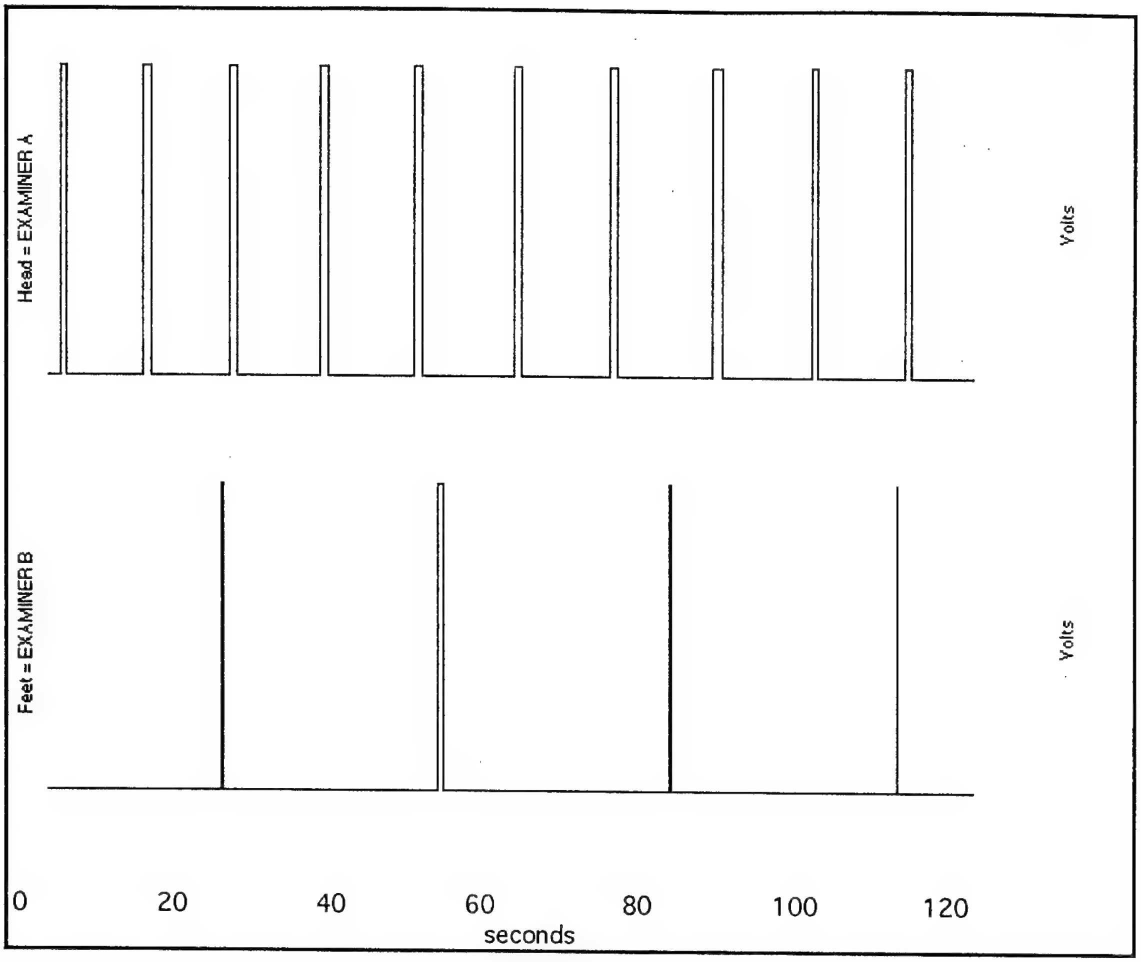

Head = EXAMINER A
Volts
Feet = EXAMINER B
Volts
0
20
40
60
80
100
120
seconds

Figure 10a.

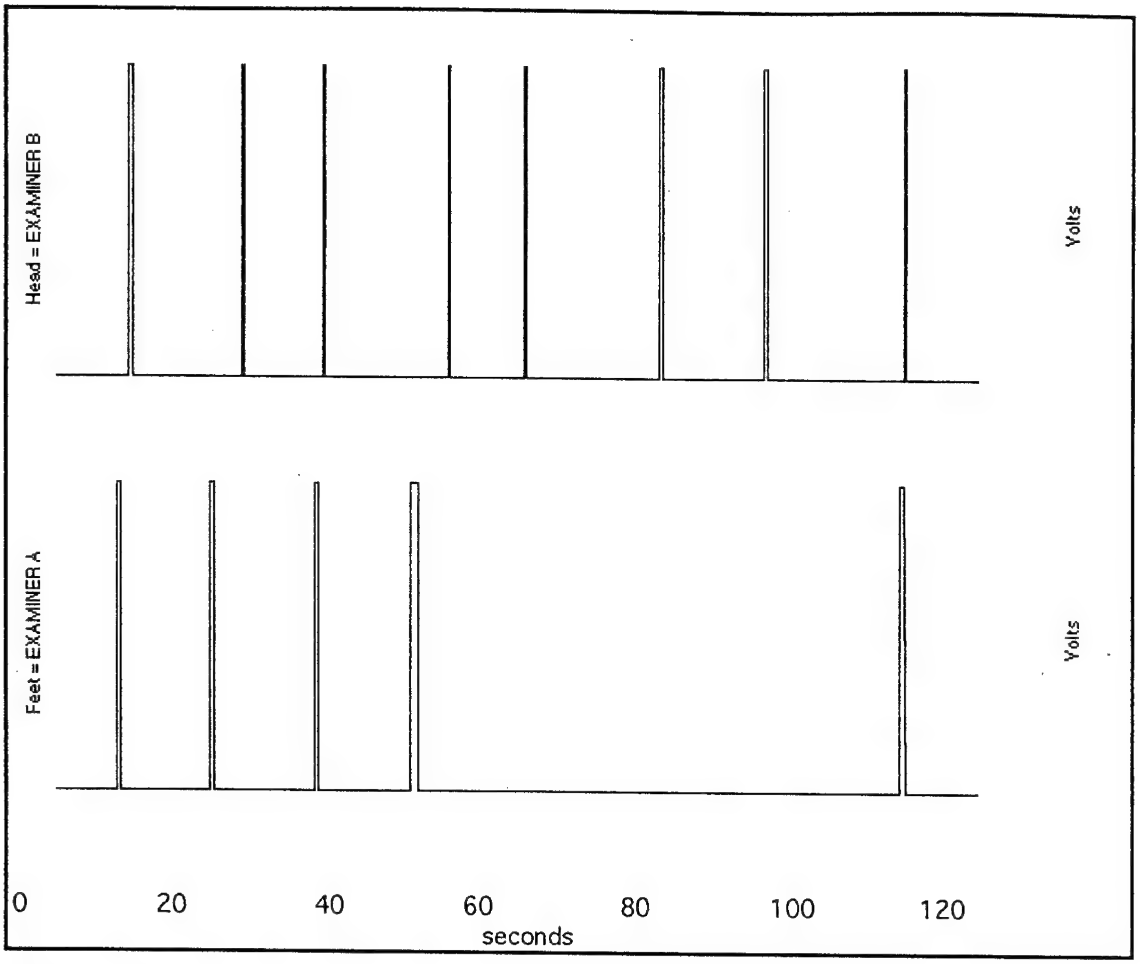

Head = EXAMINER B
Volts
Feet = EXAMINER A
Volts
0
20
40
60
80
100
120
seconds

Figure 10b.

TABLE 1

	n*
1. Had complications at birth	3
2. Injured in a motor vehicle accident	8
3. Injured in an accident other than vehicle	12
4. Head injury with loss of consciousness	1
5. Had surgeries	14
6. Currently experiencing pain	15
7. Had major dental work in the past	6
8. Currently under physician's care	7
9. Currently taking medication	7
10. Has a learning disability	0
11. Has a scoliosis	6

Table 1. Medical History Characteristics

*** Number does not total 28 because subjects appear in multiple categories.**

TABLE 2

		Mean	SD	Range
Examiner A				
	Pooled	4.37	1.20	0-6.86
	Head	4.83	1.17	0-6.86
	Feet	3.91	1.04	0-5.49
Examiner B				
	Pooled	3.21	1.58	0-8.42
	Head	3.28	1.63	0-5.71
	Feet	3.14	1.54	0-8.42

Table 2. Mean, Standard Deviation and Range of Craniosacral Rate (in cycles per minute) as Measured by Each Examiner.

TABLE 3

Source	df	SS	MS	F	P
Subjects	27	120.88			
Examiners	1	75.37	75.37	28.02	<.001
Examiners* Subjects	27	72.63	2.69		
Examiners @ Head				35.79	<.05
Examiners @ Feet				8.69	<.05
Location	1	15.62	15.62	13.06	.001
Location* Subjects	27	32.28	1.20		
Location @ Examiner A				20.89	<.05
Location @ Examiner B				.44	NS
Examiner* Location	1	8.70	8.70	7.98	.009
Examiner* Location* Subject	27	29.44	1.09		

Table 3. Repeated Measures ANOVA Results.

Table 4

	ICC(2,1)	r
Intrarater Reliability		
Examiner A at the Head	.18	.17
Examiner A at the Feet	.30	.30
Examiner B at the Head	.26	.27
Examiner B at the Feet	.29	.29
Interrater Reliability		
At the Head	.08	.12
At the Feet	.19	.23

Table 4. Intrarater and Interrater Intraclass Correlation Coefficients (ICC) and Pearson's r Correlation Coefficients.

TABLE 5

Source	df	SS	MS	F	P
Subject	27	120.88	4.48	3.39	.001
Examiner	1	75.37	75.37	57.14	.000
Location	1	15.62	15.62	11.84	.002
Trial	1	.03	.03	.03	.874
Examiner * Subject	27	72.63	2.69	2.04	.030
Location * Subject	27	32.28	1.20	.91	.600
Trial * Subject	27	39.80	1.47	1.12	.382
Examiner* Location* Subject	27	29.44	1.09	.83	.690
Examiner* Trial* Subject	27	38.36	1.42	1.07	.422
Examiner* Location* Trial	1	3.66	3.66	2.77	.106
Location * Trial* Subject	27	43.08	1.60	1.21	.305
Residual	30	39.57	1.32		
R-Squared for the model = .923					

Table 5. Custom-Modeled, Factorial ANOVA Results.

APPENDIX A

Medical History Questionnaire
For Craniosacral Rhythm Rate Study

PLEASE READ BEFORE FILLING OUT QUESTIONAIRE.

- Please fill out the questions below to the best of your knowledge.
- If you answered **YES** to any of the questions please give a brief explanation. If there is not enough room on the front of this sheet for your answer, please continue on the back.
- All your responses are **CONFIDENTIAL**. Please **DO NOT** write your name or other identification on this sheet.
- This information will be used by the researchers for the purpose of better understanding the data obtained in this study. This information may be compiled as group data for future publication.

1. Did you have any complications at birth?

2. Have you been injured in a motor vehicle accident?

3. Have you been injured in an accident other than vehicle?

4. Have you ever had a head injury involving loss of consciousness?

5. Have you had any surgeries?

6. Do you currently experience pain? If yes, where?

7. If you answered yes to question 6., is this pain due to any of the trauma listed above?

8. Have you had major dental work in the past?

9. Are you currently under a physician's care? If yes, for what problem(s)?

10. Are you currently on medication?

11. Do you have a learning disability?

12. Do you have scoliosis?

Please do not write below this line. For administrative purpose only.

Date______________ Subject Number______________________

APPENDIX B

UNC Hospitals
Chapel Hill, North Carolina

UNC-CH Study# 96-MAHP-272

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

TITLE OF STUDY: Simultaneous Palpation of the Craniosacral Rate at the Head and Feet: Rate Comparison, Intrarater and Interrater Reliability, and Rate Lag Time.

Principle Investigator: Joseph Scott Rogers, BS, PT
Capt, USAF, BSC
Phone Number: 919-408-3022

Co-Investigators: Dr. Philip L. Witt, PhD, PT
Dr. Michael T. Gross, PhD, PT
Dr. Perry A. Genova, PhD
Jon D. Hacke, MS, PT
Dr. Charity Goodwin-Johansson, PhD, PT, GCS
Laurel Wilkinson, BSRN

You are asked to take part in a research study under the direction of Joseph S. Rogers, BS, PT and faculty advisor Dr. Philip L. Witt, PhD, PT. Other professional persons who work with them may assist or act for them.

You will be one of approximately 20 subjects in the research study.

Purpose:

The purpose of this research study is to investigate the craniosacral rate. Some doctors claim that all living persons have a craniosacral rate. They believe that the craniosacral rate starts as a fluid pulse within the skull cavity. They believe that this fluid pulse causes the head to expand and contract slightly and the feet to move slightly. These doctors believe the craniosacral rate is important because they palpate the head expansion and contraction or feet movement to examine the craniosacral rate in their patients and attempt to influence the rate with hand pressure as part of their

treatment procedures. Our research is going to study the craniosacral rate by having two examiners palpate the craniosacral rate at the same time on the same person. Dr. Goodwin-Johansson and Ms. Wilkinson are both trained to feel the craniosacral rate by placing their hands on a person's body. In our research, Dr. Goodwin-Johansson and Ms. Wilkerson will be palpating the craniosacral rate at your head and your feet. We will then compare craniosacral rates at the head and feet, determine how reliable the examiners are at measuring the rates, and if the head rate starts before the feet rate.

<u>Duration</u>:

Your participation in this study will be a one-time visit that will last for approximately 1 hour.

<u>Procedures</u>:

When you arrive at our office in Room 212, Carr Mill Mall, located in Carrboro above the Weaver Street Market, the following things will take place to allow us to collect the data we need:

1. Joseph Rogers will greet you, introduce you to Dr. Goodwin-Johansson, Ms. Wilkinson, and any other assistants. He will show you all the equipment that will be used in this research study and answer any initial questions you have. He will then have you read and sign this consent form. A copy will be given to you after you sign.

2. You will be asked to fill out a brief and confidential medical questionnaire.

3. Mr. Rogers will ask you to lay down on a standard treatment table. You may be asked to remove your shoes and socks so that Dr. Goodwin-Johansson and Ms. Wilkinson can feel your craniosacral rate at the feet.

4. Dr. Goodwin-Johansson and Ms. Wilkinson will be placed by Mr. Rogers at your head and feet.

5. A sheet will be placed so that Dr. Goodwin-Johansson and Ms. Wilkinson cannot see each other. This sheet will hang from the ceiling and will be at about waist level.

6. After 5 minutes, Mr. Rogers will then ask Dr. Goodwin-Johansson and Ms. Wilkinson to begin palpating the craniosacral rate. The examiner at the head will gently cradle your head in their hands and

the examiner at the feet will place their hands lightly on your feet. After both examiners have begun acquiring the rate for 30 seconds, Mr. Rogers will collect 90 seconds of data and then ask the examiners to stop. The craniosacral rate will be recorded by Dr. Goodwin-Johansson and Ms. Wilkinson stepping on silent foot switches placed on the floor.

7. Procedure number 6. will be repeated once more. Then Mr. Rogers will ask Dr. Goodwin-Johansson and Ms. Wilkinson to switch positions and procedure number 6 will be repeated two more times. Dr. Goodwin-Johansson and Ms. Wilkinson will palpate the craniosacral rate two times each on your head and feet.

8. Mr. Rogers will then remove the sheet and have you sit-up. This will complete your participation in the study. Mr. Rogers, Dr. Goodwin-Johansson, and Laurel Wilkinson will answer any questions you have at that time.

Exclusions: Because we require palpation at both feet, lower extremity amputees are excluded from this study. All other healthy persons may participate in this study.

Risks and Discomforts:

Participation in this study is highly unlikely to place you at risk or cause you any discomfort. Though the researchers have made every effort to make this research study as easy and as comfortable as possible on the participants, some risks/discomforts may be unforseeable. If at anytime during this research you experience any discomfort the research procedure will be stopped and adjustments made to enhance your comfort as much as possible.

Benefits:

There will be no specific benefits to you other than the satisfaction of participating in a research study designed to add to the knowledge base of physical therapy. This research study will benefit the medical community by making a unique contribution to the knowledge base of medicine. In turn, it is possible this information could be used for the benefit of future patients.

New Findings:

You will be given any new information gained during the course of the study that might affect your willingness to continue your participation.

<u>Confidentiality</u>:

Every effort will be taken to protect the identity of the participants in this study. However, there is no guarantee that the information cannot be obtained by legal process or court order. No one will observe you during data collection except Mr. Rogers, Dr. Goodwin-Johansson, Ms. Wilkinson or other research assistants designated by Mr. Rogers. No subjects will be identified in any report or publication of this study or its results.

<u>Financial Costs of the Research</u>:

You will not incur any costs or fees for participating in this research study except the possible cost of transportation to and from Carr Mill Mall in Carrboro.

<u>Payments to Participants</u>:

You will receive no payment for your participation in this study.

<u>Right to Refuse or to Withdraw From the Study</u>:

Your participation is voluntary. You may refuse to participate, or may discontinue your participation <u>at any time</u> without penalty, or jeopardizing your continuing medical care at this institution, or losing benefits you would otherwise be entitled to.

Joseph Rogers has the right to stop your participation in the study at any time. This could be because you have had an unexpected reaction, or have failed to follow instructions, or because the entire study has been stopped.

<u>Offer to Answer Questions</u>:

You have the opportunity to ask, and have answered, all your questions about this research. If you have other questions, or if a research-related injury occurs, you may call Joseph Rogers, BS, PT at (919) 408-3022 or his faculty advisor, Dr. Philip L. Witt, PhD, PT at (919) 966-4708.

<u>Institutional Review Board Approval</u>:

This project has been approved by the Committee on the Protection of the Rights of Human Subjects at the University of North Carolina at Chapel Hill. If you believe that there is any infringement upon your rights, you may contact the Chairman of the Committee, Ernest N. Kraybill, M.D. at (919) 966-1344.

Subject's Agreement:

I have read the information provided above. I voluntarily agree to participate in this study. After it is signed I understand I will receive a copy of this consent form.

____ ____________
Signature of Research Subject Date

____ ____________
Signature of Person Obtaining Consent Date

APPENDIX C

The Controversy of Cranial Bone Motion: A Literature Review

by
Joseph S. Rogers, PT, Capt, USAF, BSC

The Controversy of Cranial Bone Motion: A Literature Review

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Abstract: Cranial bone motion continues to stimulate controversy. This controversy affects the general acceptance of some intervention methods used by physical therapists, namely, cranial osteopathic and craniosacral therapy techniques. Core to these intervention techniques is the belief that cranial bone mobility provides a compliant system where somatic dysfunction can occur and therapeutic techniques can be applied. Diversity of opinion over the truth of this concept characterizes differing viewpoints on the anatomy and physiology of the cranial complex. Literature on cranial bone motion was reviewed for the purpose of better understanding this topic. Published research overall was scant and inconclusive. Animal and human studies demonstrate a potential for small magnitude motion. Physical therapists should carefully scrutinize the literature presented as evidence for cranial bone motion. Further research is needed to resolve this controversy. Outcomes research, however, is needed to validate cranial bone mobilization as an effective treatment.

Key Words: Cranial bone motion, cranial osteopathy, craniosacral therapy

Introduction

Cranial osteopathy and craniosacral therapy are in widespread use today by a number of physical therapists, osteopathic physicians, chiropractors and other health and wellness providers both in the United States and abroad (14,15). Craniosacral therapy is commonly practiced by physical therapists in this country and continuing education advertisements under this name are often seen in physical therapy related publications (47).

Core to cranial osteopathy is the belief that the cranial vault is a mobile, compliant structure. The originator of this approach is Dr. William G. Sutherland, D.O.. Within cranial osteopathic circles is the well known story of a young Dr. Sutherland, who as a medical student at the turn of this century walked past an exhibit of a disarticulated skull and observed the greater wings of the sphenoid bone. His mind automatically compared them to the gill plates of fish and he wondered if perhaps the skull bones were not mobile and involved in some sort of respiratory process. Twenty years later this concept of cranial bone motion still nagged at him and he began self-experimenting using a helmet made of leather and thumbscrews. From this initial self-experimentation to later successes in the clinic, the practice of cranial osteopathy was conceived. Based on Dr. Sutherland's theories of cranial bone motion, cranial osteopathy represented a systematic approach to evaluating and treating dysfunction occuring within the articulations of the skull. Adding credibility to this new discipline was Dr. Sutherlands' astounding knowledge of anatomy coupled with a very strong commitment for taking a scientific approach to patient care (21).

More recently, craniosacral therapy has been utilized as a method for evaluating and treating patients. Founded by Dr. John E. Upledger, D.O. in the 1970's, craniosacral therapy shares with cranial osteopathy a common theoretical belief in cranial bone motion. Practitioners of craniosacral therapy suggest that periodic fluctuations in cerebrospinal fluid pressure give rise to rhythmic motion of the cranial bones and

sacrum. This rhythm is called the craniosacral rhythm. Craniosacral therapists suggest that by applying selective pressure to the cranial bones, they can manipulate the craniosacral rhythm to achieve a therapeutic outcome in their patients.

Little research has been done on cranial bone motion and agreement to even its existence remains controversial. Though there is more to cranial osteopathic and craniosacral therapy theory than cranial bone motion, without this motion much of the rationale, and many clinical techniques are invalidated. The purpose of this paper is to present the controversy over cranial bone motion, and to review the cranial bone literature. Implications of this review and directions for future research are discussed.

Controversy

Classical anatomists generally hold the firm belief that the cranial sutures fuse in adulthood, though it is conceded that there is much individual variation as to exactly when this fusion takes place. The exception to this rule is the metopic suture of the frontal bone which fuses by the age of two years (28). Presupposing cranial suture fusion would therefore make any functional movement between the bones of the skull highly unlikely and certainly unphysiological (8). This is probably the prevailing view taught in most physical therapy programs.

Practitioners of cranial osteopathy and craniosacral therapy see the skull in a different light. In this paradigm the cranial sutures, again excepting the metopic suture, remain unfused throughout life. Practitioners believe that a small amount of motion between the cranial bones is possible. The unfused sutures between these bones allow for this motion to occur (37,47).

In assessing factors that affect intracranial pressure, conventional physiologists do not consider the cranial sutures to play any significant role. The cranium and spinal canal are closed systems. The calvarium is assumed to be an unyielding structure that rigidly contains brain tissue, blood, and cerebrospinal fluid. Any increase in volume in

one of these contents must be accompanied by a decrease in the others or else an increase in intracranial pressure will occur. This concept, known as the Monro-Kellie doctrine, helps to explain such events as the decrease in cranial cerebrospinal fluid volume that occurs during a Valsalva maneuver (1,20). However simple this may seem, in reality the relationship between intracranial pressure and volume is a nonlinear one. In other words, some cranial vault compliance exists within the system. Some authors have proposed that cranial sutures contribute to this compliance by allowing motion between cranial bones (2,13).

Different physiologic episodes increase intracranial pressure and theoretically could cause cranial bone motion. Such episodes include the already mentioned Valsalva maneuver, as well as blocking venous outflow, an increase in arterial blood flow, hypercapnea, and transient apnea (1,2,20). Theoretical explanations for cranial bone motion invariably describe rhythmic fluctuations in cerebrospinal fluid pressure producing tension on the dura and its osseous connections. These fluctuations are commonly referred to as the craniosacral rhythm and are viewed as a naturally occurring physiologic phenomena just like respiration or heart rate. This rhythm completes 6 - 12 cycles per minute and is palpable anywhere on the body. Various reasons are given for the cause of these fluctuations (47). Upledger (45) presents a Pressurestat Model which presumes alternating on/off cycles of cerebrospinal fluid production lasting about three seconds each. These cycles are triggered by a neurologic feedback mechanism involving stretch and compression receptors in the sagittal suture.

Conventional medical literature states that a fused cranial suture creates a rigid calvarium which physiologically responds according to the Monro-Kellie doctrine. Cranial osteopathic and craniosacral therapy literature describe a cranial complex which remains mobile throughout life and is compliant to fluctuations in cerebrospinal fluid pressure.

<u>Anatomy of Suture Closure</u>

Theories promoting cranial bone motion all suggest the notion that the cranial sutures remain unfused throughout life. Critics of these theories infer that cranial sutures fuse sometime in early adulthood. Investigations into cranial suture closure are therefore central to the issue of cranial bone motion. Several investigators have studied suture closure in both primates and humans.

Retzlaff et al (34,36,39) performed a number of tissue sample studies on primate cranial sutures using light and scanning microscopy. Age of animals, location of suture sample on the skull, and number of tissue observations were uniformly missing from these published reports. Photographic details of findings were also absent from these studies, making independent analysis of findings impossible. Different lab techniques were incorporated and detailed in the articles. Histological findings followed the general five layered pattern of fibers and cells as reported by Pritchard (33). Retzlaff reported that adult sutures showed no evidence of fusion. The authors assumed that since collagenous bundles found within the sutures frequently displayed a wavy pattern that elongation of these fibers was possible. The authors further assumed that "elastic" fibers bordering these collagen bundles "may function to control elongation of the collagen bundles." Whether the authors are actually referring to elastin fibers was not made clear. Unfortunately, because of inadequate information given, no substantive conclusions can be drawn from these studies.

A very detailed approach to studying suture closure in humans was conducted by Todd and Lyon (43,44). Starting with an initial cadre of 427 male skulls of verifiable age they performed visual inspection of ecto- and endocranial suture surfaces. Since the authors a priori concluded that cranial sutures do fuse sometime during adulthood, a total of 81 were rejected from the study because of abnormal progress of suture closure, either precocious or absent. The main cited cause for rejection was delayed union. From the remaining sample of 346 skulls, which the authors found "remarkably uniform and

harmonious in the information it now gave regarding suture closure", progress of suture closure for a number of sutures was carefully described. Generally speaking, suture closure began in these specimens between 20 to 30 years of age. Sagittal, coronal, and lambdoidal sutures were completely closed by 31 years, 38 years, and 47 years, respectively. The masto-occipital and parieto-mastoid did not close until 70 to 80 years. The spheno-parietal and spheno-frontal sutures close around 60 years; complete closure of spheno-temporal is rare. An operating definition used by Todd and Lyon that we believe significantly influenced the results of this study should be noted. Todd and Lyon defined as "united", those sutures that displayed what they called a "lapsed union". This type of sutural union was actually a failure of the suture to close in the presence of a concentration of bone along the edges of the articulation. Counting "lapsed unions" as fused sutures may have favored the data toward early suture closure. The authors concluded that although suture closure exhibits a definite periodicity, individual variability makes it unwise to depend upon stage of closure as an age marker. The authors, in reference to earlier works on suture closure by L. Bolk, stated they too had found skulls in which closure of sutures was either very delayed or never takes place. These "antithetic" skulls were eliminated from this study. One can conclude from Todd and Lyon's work that probably a chronological pattern of suture closure does exist, but there is a high degree of individual variability and some cranial sutures may never close.

Often referenced in the osteopathic literature, Pritchard's (33) classic study on suture development used only fetal or newborn human subjects. His proposal that viable sutures may allow slight motion is therefore limited to this population alone and does not shed much light on sutures in adults. Also, there is evidence to suggest that the five cellular layers described by Pritchard may not even persist into adulthood; again reflecting the limitations of drawing conclusions from this study (22).

The use of orthodontic appliances to stimulate craniofacial suture remodeling and correct malrelationships of these bones is well known. Sutural fusion makes malrelationships less amenable to treatment and so knowing when these sutures fuse is essential to the timing and placement of these appliances. In a study that we believe sets a standard of excellence in suture closure research, V. G. Kokich (22), investigated a method for documenting age-related changes in a craniofacial suture. Using radiographic and histological techniques he clearly documented age related changes in the frontozygomatic suture. This suture was ideal for study because its relatively small size allowed it to be examined along its entire length. Any evidence of bony union affecting suture patency was positively identified. Sixty-one human specimens were used and were categorized according to age at 5-year intervals. Results demonstrated that the human frontozygomatic suture does not undergo synostosis until the eighth decade of life and is not completely fused by the age of 95. The morphology of this suture became increasingly irregular with advancing age because of the formation of bony interdigitations between the suture surfaces. Drawing from other investigators, Kokich stated this irregularity reflected the length of time the human frontozygomatic suture remains patent and the tensile forces produced across the suture by the masseter muscle. Direction of collagen fibers within the suture also consistently reflected tensile forces. Kokich concluded that the frontozygomatic suture remains a functional articulation until late in life and is capable of orthodontic remodeling during adulthood.

Retzlaff et al (38) performed gross and microscopic analysis of sagittal and parieto-temporal sutures from 17 cadavers ranging in age from 7 to 78 years of age. Results were described without supportive documentation. They reported no evidence of sutural obliteration by ossification in any of the samples studied. Sutural structure reported was consistent with primate findings including the existence of blood vessels and nerve fibers within the sutures. Age related changes noted are a reduction in number of collagen bundles and increased interdigitation of approximated bone edges.

The authors conclude that sutural structure is such that movement of cranial bones is possible at all ages studied. As before from this group of investigators, inadequate information is given in which to base any independent conclusions.

Sukekawa (42) looked at adult human sagittal suture using scanning electron microscopy. Neither sample size or ages were reported. He categorized the sutures as being either preadhesion or postadhesion. In the preadhesion suture he noted numerous blood vessel holes surrounding calcified matrix fiber bundles. These bundles were oriented in a parallel, non-fused fashion. Postadhesion sutures were in a 'dormant state'. Here the calcified bundles were oriented either irregularly or in parallel as before. In the irregular pattern, scattered calcium globules about 10 microns in diameter were often observed. Sukekawa describes the adult suture as being in a resting stage, having a distinct border, and being adherent rather than fused.

A general statement about whether and when suture obliteration occurs in adulthood cannot be made from existing research. Kokich's approach to this problem should provide a model for future studies and gives a compelling argument for the viability of at least one human cranial suture well into adulthood.

Biomechanics of Cranial Suture

Cranial sutures during skull growth are generally viewed as dynamic structures that respond to extrinsic biomechanical forces by changing morphology as bones overlap and interdigitate (19,25,29,30). Apparently less is known regarding sutural mechanics in the adult (19).

Jaslow (19) observed mechanical properties of cranial sutures in adult goats. Cranial sutures displayed significantly different properties than cranial bone. Bending strength of cranial suture was positively correlated with a high degree of bone interdigitation yet did not exceed that of bone. The difference in strength between bone and cranial suture was attributable to the presence of collagen in the suture. Age of the

animal had no effect. Increasing the rate of loading only affected the more highly interdigitated sutures which displayed lower bending strengths. All sutures tested had higher energy absorbing capability than bone, supporting the hypothesis that adult cranial sutures may perform a shock absorbing role.

A study including embalmed and unembalmed human suture material done by Hubbard et al (16) has important implications for future research in cranial bone mobility. Though differences in bending strength were not as striking as in Jaslow's work, cranial suture compliance (mid-span deflection caused by a unit of load) was significantly more than equivalent layered bone. The embalming process significantly strengthened the suture and therefore decreased compliance and increased bending strength compared to unembalmed samples. The authors concluded that embalmed suture is generally as strong as adjacent bone in bending to failure strength. Therefore, using embalmed cadavers is not a valid approach for making assumptions about cranial bone motion in living persons.

To better understand traumatic head injury, mathematical and mechanical models have been developed to simulate responses of the human head and its constituent structures to various externally applied forces. Cranial bone is one such constituent structure. Cranial bone is in essence a layered panel consisting of inner and outer tables of compact bone separated by a cancellous diploë. Layered beam theory is a mathematical model used to predict the mechanical responses of a layered panel material, such as cranial bone, from the properties and geometry of its constituent materials. Hubbard (17) has shown that the application of layered beam theory for predicting bending responses in cranial bone is valid. Such application for cranial suture does not exist. Jaslow (19) points out that the "mechanical behavior of a complex sutural joint cannot be predicted according to behavior of its individual components".

Biomechanical studies of the adult cranium clearly demonstrate that cranial suture has mechanical properties quite distinct from that of adjacent bone.

Cranial Bone Movement Studies

Direct measurement of cranial bone motion has piqued the interest of practitioners cranial osteopathy and craniosacral therapy as well as other researchers (13,31). Among the latter, Ouhdof (31), looked at a hemodynamic influence on skull growth. Using beagle puppies, he attached strain guages to the frontal and sagittal bones. Adult beagles served as controls. Movement between the bones of about 5 -10 microns was recorded and was synchronous with aortic flow and ECG . No movement was detected in any of the adult dogs. Oudhof states that the lack of movement in adults could reflect a lack of equipment sensitivity or other physiological processes compensating for cranial volume in adult animals.

Adams et al (2) researched parietal bone mobility in adult cats. Using multiplanar strain guages, the influence of externally applied forces and changes in intracranial pressure on inducing or restricting parietal motion was analyzed. Significant motion did occur, but it was clear that considerable interanimal variability existed in the amount of motion observed. Lateral head compression caused sagittal suture closure and inward rotation of the parietal bones. Increasing intracranial pressure caused a widening of sagittal suture and outward rotation of parietal bones as did direct pressure on the sagittal suture. All animals demonstrated lateral parietal bone motion in response to intracranial injections of artificial cerebrospinal fluid. The magnitude of this motion varied by animal and ranged from approximately 17 to 70 microns. Restraint in a stereotaxic frame decreased motion responses. Using data from the same study, Heisey & Adams (13) described the behavior of total cranial compliance to increased intracranial pressure. At low intracranial pressures, cranial sutures are mobilized but cerebrospinal fluid and blood volume shifts are primarily responsible for compliance. At higher pressures, fluid shifts are maximized and cranial bone movement is theorized as the only mechanism counteracting any further increase in pressure.

Researchers affiliated with the Michigan State University-College of Osteopathic Medicine have done several studies on cranial bone mobility using adult primates. Micheal & Retzlaff (27) performed direct measurement of right parietal bone motion using a screw attachment and a displacement transducer. With the primate's head firmly immobilized in a stereotaxic frame, bone displacement, mean arterial blood pressure, heart and respiration rates were simultaneously measured. Central venous pressure was measured in two animals. Spontaneous cranial motion and the effects of applying external forces and passive spinal motion were recorded. Results showed two patterns of spontaneous parietal bone motion. One pattern was synchronous with respiration rate. This was superimposed over a second, slower oscillatory pattern consisting of 5-7 cycles per minute that was not attributable to either heart rate, respiration rate or central venous pressure. Force applied to the skull in various locations generally produced motion between the parietal bones. Spinal extension or flexion each produced a characteristic pattern of parietal motion.

Retzlaff et al (35) elaborated on the above study by recording parietal bone displacement with the primate's head loosely mounted in the stereotaxic frame rather than being firmly fixated as before. Also different in this study is that force transducers were attached to both parietals via screw-eye screws placed in the "midpoint" of the bones. Respiration rate and blood pressure were measured using direct methods. As in the first instance, two patterns of spontaneous parietal bone motion were seen, however this time the slow and rapid wave patterns directly corresponded with respiration and cardiac activity. By increasing the level of head fixation within the stereotaxic frame, the left and right parietals assumed patterns of motion independent from each other and displayed a rapid oscillatory pattern distinct from cardiac activity.

What is troubling in the previous two studies is a lack of detail in experimental methods. This absence of information is clearly apparent when compared to the well described methods of Oudhof (31) or Adams et al (2). Control of transducer placement

and alignment is essential in isolating cranial bone motion from extraneous sources. Choice of transducer placement can account for measuring "spontaneous" parietal bone motion when the head is not fixated in a stereotaxic frame. For example, such spontaneous motion could occur from subtle head motion caused by respiration. Poor description of methods only serves to cast doubt on whether the transducers where actually measuring cranial bone motion. Vagueness in methodology prohibits independent replication and meaningful interpretation of results in the above two articles.

In another primate cranial bone motion study out of Michigan State University, St. Pierre et al (40) gave a brief account of detecting cranial bone motion in squirrel monkeys. The authors stated that "Relative movements of cranial bones that may have physiologic significance were observed in squirrel monkeys." No sample size, animal ages, or even experimental conditions were given so conclusions from this report are impossible.

All the clinical meaning attributed to cranial bone motion has obviously stimulated research on humans. A particularly interesting study performed on live subjects was done by an osteopathic physician, Dr. Viola Frymann (9). In conjunction with an electronics engineer, Dr. Frymann gradually developed a non-invasive apparatus for mechanically measuring changes in cranial diameter. The apparatus was composed of a large, metallic U-shaped frame with a differential transformer placed laterally on each side. Differential transformers convert displacement of a metallic rod into an analog signal. A subject placed their head into the U-shaped frame and the metallic rods of the differential transformers were placed laterally against the subject's cranium. Changes in skull diameter were measured by displacement of the metallic rods. The author described the various steps of measurement apparatus development. Results are then presented from each step. Cranial motion was recorded simultaneously with either thoracic respiration or volumetric changes in the finger or forearm. Sample recordings were presented as evidence of findings. Sample subject information such as

age and sex were largely missing. Subjects were selected on the basis of having mobile cranial mechanisms as determined by cranial osteopathic evaluation. The author concluded, on the basis of extensive recordings, that cranial motility exists and can occur in a rhythmic pattern that is slower than and distinct from cardiac and respiration rates. The magnitude of motion was estimated to be between 10 and 30 microns. The author related cyclic changes in limb volume to cyclic changes in head diameter. More important, perhaps, Dr. Frymann implicitly concluded that cranial motion can be instrumentally recorded in living humans using non-invasive techniques. Despite obvious shortcomings in research design, this study provides evidence of rhythmic diameter changes in the living cranium which could be reflective of cranial bone motion.

Other studies have measured dimension changes of the cranium using more invasive techniques. Two teams of researchers independently demonstrated the positive correlation between intracranial pressure and bitemporal skull diameter. Heifetz and Weiss (12) used strain gages attached to a Gardner-Wells tong-like device. This device was attached to two comatose patients via pins inserted into the outer plate of the cranium approximately 6 cm above the external auditory meatus. Intracranial pressure was simultaneously measured. Each time the intracranial pressure was increased between 15 and 20 mm Hg, the skull tong pins were pushed apart. The average magnitude of separation varied between the subjects and was reported as .78 microns and 3.7 microns. Pitlyk, Piantanida, & Ploeger (32) placed strain gages on Gardner-Wells tongs. They first affixed the tongs to a dried human skull and found that by applying an external force to the skull they were able to produce a measurable, reproducible distortion. This distortion was maximal over the parietal bones. Next, they placed the tongs on a fresh cadaver. In this case, strain gage output was closely correlated to a volume of saline injected intracranially. Finally, the tongs were placed on six live dogs. Intracranial pressure was manipulated via either inflating a balloon catheter inserted into the intracranial subarachnoid space or by saline injected into the spinal

subarachnoid space. Intracranial pressure was monitored during the experiments. Results showed that strain gage output of the tongs correlated very well with intracranial pressure measurements. In other words, skull expansion occured with an increase in intracranial pressure. Pressure changes as little as 2 mm Hg could be detected with the tongs. Magnitude of skull expansion was not reported. Strip chart output from the tong strain gages demonstrated minute skull distortion due to cardiac systole superimposed over larger changes because of increased intracranial pressure. The authors concluded that using the tongs to measure cranial diameter changes was a sensitve enough method for use in monitoring intracranial pressure.

Studies that measure gross diameter changes in the skull, such as the last three cited, do not directly measure cranial bone motion. From these studies it is not clear whether diameter changes incorporate actual motion at the cranial sutures, flexure of bone itself, or some combination of the two. Therefore, interpretation of the results of these studies cannot conclude with certainty that motion occurs at the sutures. Rather, these studies provide indirect evidence for cranial bone motion by assuming that given a change in intracranial pressure, flexion/expansion at the suture would occur prior to flexure of bone. Previously cited anatomic and biomechanical research provides some support for this assumption.

White & White (48) developed a radiographic method to locate points on an X-ray and measure changes in position of these points with accuracy. This method requires locating the central beam of the X-ray as a reference point, identifying the three-dimensional position of a point on the X-ray in relation to this reference point, and calculating distance between points using the Pythagorean Theorem. White & White suggest that this technique could be used to detect small motions between bones and quantify the effects of manipulative treatment. Using this radiographic method, along with plaster models of the mouth and other measurements, White, White, & Baldt (49) studied the relationship between craniofacial bone movement and somatic dysfunction in

humans. Manipulation of the zygomae, maxilla, and temporal bones provided the experimental condition. They reported movement between these bones along suture lines. Maxillary widening up to 3 mm and separations of the zygomae-maxillary suture in excess of 1 mm were noted. Individuals varied in the amount of motion observed. The authors reported that changes in maxillary bone position cause an ipsilateral palpable tension in the C1 area. This tension, equivocated to somatic dysfunction by the authors, is relieved by manipulating the facial bones, placing wax between the molars, and having the patient swallow.

Kostopoulos (23) applied a traction force to the frontal bone of an embalmed cadaver to measure elongation of the falx cerebri. Forces far exceeded therapeutic levels. Since a distinction between flexure of cranial bone and actual motion occurring at the suture was not made, no conclusions about cranial motion can be drawn from this study. Bergevin et al (4) attempted to measure motion across the sagittal and frontal sutures in unembalmed cadavers by increasing cerebrospinal fluid pressure. The authors introduced water into the subarachnoid space via a lumbar puncture to simulate increased cerebrospinal fluid pressure. No cranial bone motion was detected. Owing to the very advanced age of all the sample subjects and no control for actual increase in intracranial pressure, little can be concluded.

Research on cranial bone motion is obviously in its beginning stages and is far from conclusive. The possibility of motion existing appears real and worth further inquiry to describe its magnitude and meaning.

Discussion

Clinicians need to scrutinize the quality of research presented as evidence for cranial bone motion. Some of the often cited references coming from the osteopathic literature are abstracts yielding little, if any substantive information. Certainly insufficient to form conclusions. Claims that reliable palpation of craniosacral rhythm

(and therefore cranial bone motion) is possible turn out to be exaggerated when subjected to statistical analysis (50). There does exist, however, a body of credible research that presents a more convincing, but certainly not conclusive case for cranial bone motion. Anatomic studies on sutural union provide evidence that sutures may not fuse until late in life and perhaps not at all in some cases. Biomechanical evidence clearly shows that adult human suture has properties very distinct from that of cranial bone, making it highly improbable that sutures are completely ossified as some authorities have contended. Credible research has shown that cranial suture may play a significant role in cranial compliance to increases in intracranial pressure in adult humans and animals, indicating the need for revisiting the concept of a physiologically rigid cranium. Some proponents of craniosacral therapy exercise poor choice in what they adopt as convincing evidence for cranial bone motion. This only serves to undermine credibility. Quality research does exist that provides a convincing argument that at least a small degree of cranial bone motion is possible in adults. It is this research that needs find its way into discussions and bibliographies on craniosacral therapy.

A major proponent of craniosacral therapy recently claimed that, "Our research...did indeed prove beyond any doubt that (human) skull bones continue to move throughout normal life" (46). In a respected peer-reviewed journal two critics of cranial osteopathy wrote that "...it is logical to assert that movements of the bones belonging to the anterior and middle cranial fossae are impossible from the age of 8 years..."(8). Both of these statements are inconsistent with the literature review presented here. Research on cranial bone motion in living humans is scant and inconclusive. Physical therapists should be wary of blanket statements regarding cranial bone motion, either for or against. What is presented as proof is often anecdotal evidence or inadequately documented research. There has been virtually no replication of cranial bone motion studies. Many articles claiming to support cranial bone motion contain so little information on methodology and results that reproducing them would be

impossible. There is very little evidence which disproves cranial bone motion. No investigators have come forth with valid evidence that reliably shows that cranial bones do not move. Proving a phenomena beyond all doubt implies that the phenomena is observable and reproducible to the point that it becomes common knowledge within a community. This is obviously not the case with cranial bone motion. Continued professional controversy based on a lack of concrete, reproducible evidence shows that the understanding of cranial bone motion is very much in its infancy.

Future Research

Assessment of cranial bone motion is used for evaluation and treatment in both cranial osteopathic and craniosacral therapy practice. Of the two disciplines, physical therapists in this country are probably more likely to use craniosacral therapy. This is evident from material published in the journal, "Physical Therapy" (6, 7, 11, 50) and a review of continuing education advertising in our various professional publications. The use of craniosacral therapy techniques is becoming more prevalent and some therapists may use this approach exclusively (7). Yet, an acknowledged vacuum of convincing research exists, not only in the very basic foundations of craniosacral therapy theory such as the existence of cranial bone motion and craniosacral rhythm, but also in patient outcomes.

Basic research aimed at validating the existence of cranial bone motion in living adult humans needs to address three major issues. The first is to establish that cranial sutures remain unfused through adulthood. Kokich's (22) study on the frontozygomatic suture is an example of research addressing this issue and could be replicated on other cranial sutures. The second is to provide evidence that actual motion does take place between the cranial bones rather than flexure within the bones themselves in an intact skull. Pitlyk, Piantanida & Ploeger's (32) use of fresh cadaver material could serve as example research. Intracranial pressure monitoring or documentation of a given

externally applied force is essential to validating whether an appropriate level of stimulus to move cranial bones is present. Strain gages could be affixed across one or more sutures rather than using a tong-like device as in their study. The third issue is to document, through unbiased measurement, the existence of rhythmic cranial bone motion in living humans. Using information gained on suture anatomy and experimental behavior of cranial bones on appropriate cadaver material, non-invasive monitoring of cranial distortion, such as replication of Frymann's study, could provide some support for the concept of physiological motion of the cranial bones. Non-invasive monitoring of cranial distortion on patients requiring intracranial pressure monitoring would further clarify this issue by assessing the relationship between cyclic changes in pressure and cyclic changes in cranial diameter.

Another important issue with cranial bone motion is its context within the treatment paradigm of craniosacral therapy. Ideally, what we do as therapists should be developed from scientific evidence. Bergman (5) points out for pediatricians that much of their guidelines for treatment lack sufficient scientific support. We believe this holds true for physical therapists. What is, after all, the best proven treatment for a herniated disc, frozen shoulder or tension headache? Craniosacral therapy is often criticized for a lack of scientific support for its theory, especially the existence of cranial bone motion and craniosacral rhythm (6,8). Upledger (46) cites disagreement on the existence of cranial bone motion, along with other debated physiologic functions, as the reasons why craniosacral therapy is not incorporated into conventional medical practice. Craniosacral therapy is far from alone in the problem of lacking hard scientific evidence to explain what it does. Prescribing aspirin and administering general anesthesia are two of the most commonly done procedures in medicine yet there is no adequate explanation of how either works (26,41). The critical difference lies in the multiple efficacy studies justifying the use of aspirin and general anesthesia. The same is not true of craniosacral therapy. There are no published true experimental

studies demonstrating its effectiveness over other treatments, therefore, it cannot reasonably be separated from a placebo effect. The opinion of the authors is that this lack of proven efficacy, rather than poorly understood mechanisms of action, is what makes it difficult to promote craniosacral therapy as a mainstream treatment. If craniosacral therapy was demonstrated safe and more effective than comparable treatments, we do not think that disagreement over mechanisms of action would be sufficient to prevent its promotion and use within conventional practice.

Being a gentle, hands-on manual therapy, the potential risks of craniosacral therapy can be easily assessed and controlled by judicious application (14,47), just like many other things we do as therapists. The benefit to risk ratio of using craniosacral therapy certainly warrants comparing it to mainstream treatments. There are a multitude of anecdotal testimonies and informal case studies that suggest craniosacral therapy is beneficial for some patients (10,14,15,18,24,46,47) as well as some scientific support for craniosacral mechanisms (3). However, no controlled outcomes or single-subject design studies are apparent in the literature for craniosacral therapy. The fundamental question asking: "Is craniosacral therapy better than anything else we do for our patients?", cannot be answered through existing published qualitative or quantitative research. Controlled single subject studies and randomized clinical trials could provide outcome support for craniosacral therapy. Qualitative research may give insight into how and why craniosacral therapy may benefit our patients. Like other forms of past and present treatment protocols, scientific proof of its theoretical base may significantly lag behind proof of its ability to benefit patients. Quality research designed to validate theory such as measuring and describing cranial bone motion and craniosacral rhythm are essential to making craniosacral therapy more credible, efficient, and reliable to use; and this paper hopefully provides support for doing this type of research. However, even clear

evidence of this phenomena will fall short of answering the real question of whether craniosacral therapy is an effective treatment.

Conclusion

Anatomic studies on sutural union provide evidence that sutures may not fuse until late in life and perhaps not at all in some cases. Biomechanical evidence clearly shows that adult human suture has properties very distinct from that of cranial bone, making it highly improbable that sutures are completely ossified as some authorities have contended. Research on cranial bone motion has shown that cranial sutures may play a significant role in cranial compliance to increases in intracranial pressure in adult humans and animals, indicating the need for revisiting the concept of a physiologically rigid cranium. Therefore, a small magnitude of motion may be possible between the bones of the cranium. However, a number of those published studies supporting cranial bone motion lacked evidence of scientific rigor. Physical therapists should carefully scrutinize the literature presented as evidence for cranial bone motion. Further research is needed to resolve this controversy. Outcomes research, however, is needed to validate cranial bone mobilization as an effective treatment.

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SIMULTANEOUS PALPATION OF THE CRANIOSACRAL RATE AT THE HEAD AND FEET: RATE COMPARISON, INTRARATER AND INTERRATER RELIABILITY, AND ASSESSMENT OF LAG TIME

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